ACID RAIN

The science of acidic deposition

Alberta
ENVIRONMENT

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CHAPTER ONE

ACID RAIN: The science of acidic deposition

Imagine being on a tour of Canadian regions affected by acidic deposition. Your first stop is a small community north of Sudbury, Ontario. The land is barren, rocky and supports only a sparse amount of stunted vegetation. There appears to be little sign of wildlife in the area. Your tour guide explains that this area has been exposed to varying degrees of acidic deposition for close to one hundred years.

Your next stop seems to contradict your first impression of the environment's response to acidic deposition. You are standing on a hillside overlooking a beautiful lake with crystal clear water. The scene is postcard perfect, yet in this case beauty can be dangerously deceiving. "The lake", your tour guide informs you, "is a victim of acidic deposition. The water is clear only because the lake is virtually dead. Only a few very tolerant species now inhabit this aquatic environment."

These scenes are the result of an environment exposed to acidic deposition in amounts greater than can be tolerated. The long-term consequences of acidic deposition reach into the political, economic and environmental realms of our society.

Acidic deposition is a serious concern that has varying degrees of regional and global impact. The extent of the impact is dependent upon a variety of factors, including:

- concentration and length of exposure
- source and type of acidic deposition
- climate
- geological characteristics

Unlike many environmental issues that demand immediate attention, acidic deposition is a silent, gradual threat that often goes unnoticed until the damage has been done. It is estimated in Eastern Canada alone, 150,000 lakes are gradually succumbing to the effects of increasing acidity. Unless these lakes are monitored, there is often no way of realizing the actual impact until the damage has become extreme.

In North America, public perception of the issue has been shaped to a large extent by accounts of the situation in the eastern half of the continent. Media accounts, environmental interest groups, scientists and government representatives have contributed to this perception. As Albertans, we need to be aware of the global and national concerns as well as the more regional effects that deal with Alberta's situation.

How do we know the strength of an acid?

The strength of an acid or base is measured using an instrument called a pH meter. pH describes how acidic or alkaline (basic) a substance or solution is. The pH scale ranges from 0 which is very acidic to 14 which is very basic. A pH value of 7 is neutral and is characteristic of distilled water. An acid that has a pH of 4.5 on this scale would be ten times more acidic that an acid that has a pH of 5.5. A change of 1 pH unit represents a ten-fold change in concentration. The following chart illustrates the pH values of a variety of common substances.

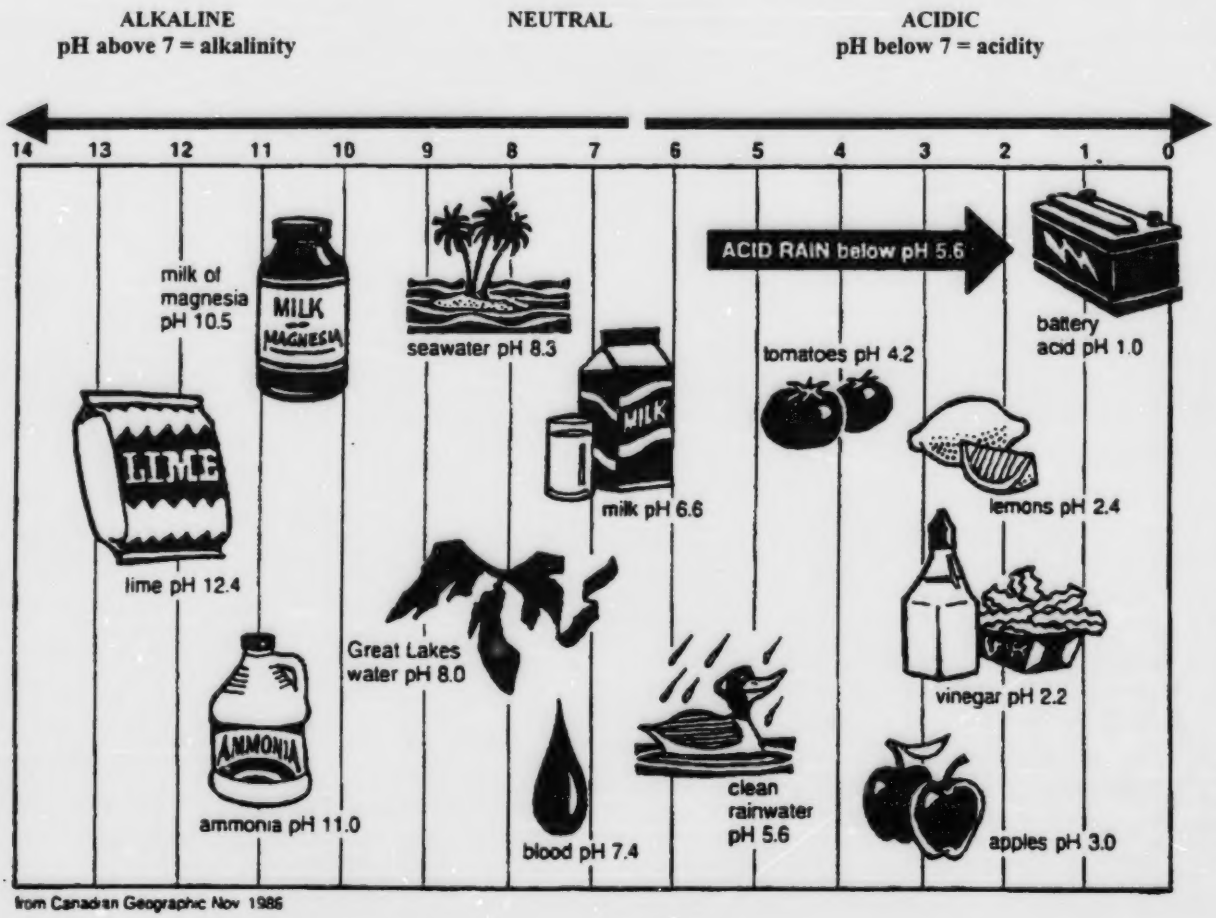


Figure 1: *pH values of common substances*

What is acidic deposition?

Often, the term acid rain is used when describing the effects of acidification on lakes and soils. The effect can be the result of both wet and dry acidic pollutants that eventually settle out of the atmosphere. These wet and dry pollutants are collectively referred to as acidic deposition.

Acid rain, snow, hail, sleet and fog are formed when dry acidic particles combine with moisture in the air to form mild acids. These fall to earth as *wet acidic deposition*. Normal rain has a pH value of 5.6. This slight acidity is the result of the rain combining with carbon dioxide to form a mild carbonic acid solution. Any precipitation that has a pH value lower than 5.6 is defined as wet acidic deposition.

If the acidic pollutants in the atmosphere do not combine with moisture, they often chemically attach themselves to dust particles in the air and settle out as *dry acidic deposition*. These dry particles will form a mild acid once they are exposed to moisture on the ground. The total effect of acidic deposition on an area is related to the amount of wet and dry acidic deposition an area is exposed to.

Sources of acidic deposition

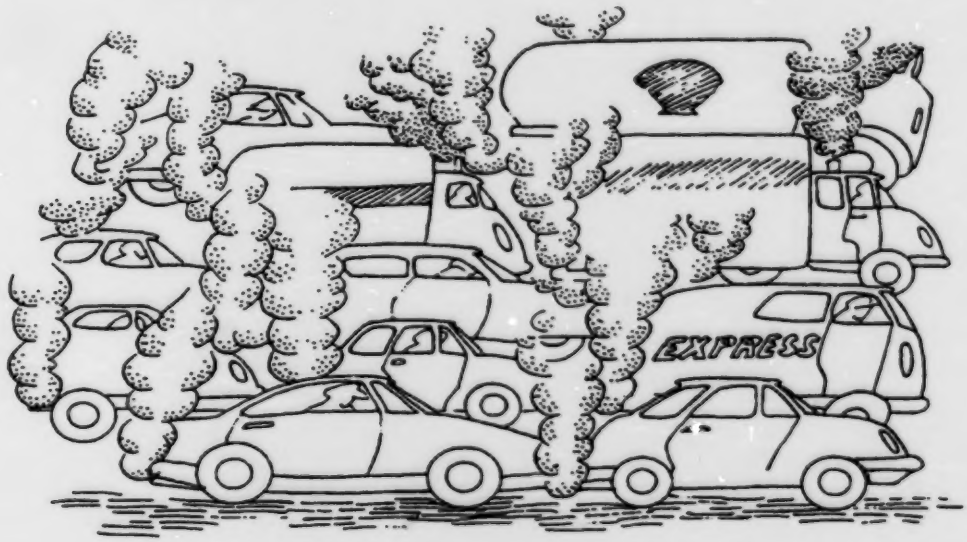
The compounds most commonly responsible for acid deposition are produced largely from human-related activities. These compounds are sulphur dioxide (SO_2) and nitrogen oxides (NO_x).

Sulphur dioxide is a by-product of several large-scale industrial processes including the burning of fossil fuels for power, heating, and transportation. Sulphur dioxide can combine with moisture in the air to form weak sulphuric acid (H_2S0_4), or it can chemically combine with dust and other airborne particles and settle out as dry acidic deposition. Coal fired power generators are largely responsible for SO_2 emissions because of the sulphur content of the coal that is being burned.

During this process, the sulphur is released and combines with oxygen during combustion to form sulphur dioxide. Non-ferrous smelting industries are also responsible for large-scale production of SO_2. The ore is heated to extremely high temperatures in order to separate the nickel, copper, lead or zinc. This causes the sulphur within the ore to be released, forming SO_2 as it combines with oxygen.

In Alberta, the main source of acidic deposition is from sour gas refineries that release SO_2 during the refining process. There are two types of natural gas in Alberta. *Sweet natural gas* is the most preferred because it does not contain hydrogen sulphide (H_2S), a poisonous gas that has a distinct rotten egg odour. *Sour gas*, on the other hand, has a high H_2S content and must be refined prior to being used. In Alberta, approximately one quarter of all natural gas reservoirs contain sour gas. The dry and windy conditions, characteristic of southern Alberta where the majority of natural gas pockets are located, contribute to an increase in widely dispersed dry acidic deposition. Other sources of SO_2 in Alberta include the processes related to refining oil sands into crude oil. SO_2 can also be produced naturally through the decomposition of organic material and events such as volcanoes and fires. These events contribute to global concentration of airborne SO_2. Human-created SO_2, however, is responsible for approximately 90% of the total amount of airborne sulphur dioxide in North America.

Nitrogen oxides include nitrogen dioxide (NO_2) and nitrogen oxide (NO). These nitrogen compounds are the second major contributor to acidic deposition. Nitrogen oxides are formed when nitrogen present in fossil fuel and in the atmosphere combines with oxygen under high temperature conditions. NO_x pollution results largely from our North American dependence on the automobile for transportation. Approximately 70% of all NO_x in the atmosphere is produced by human-related activities. The addition of fertilizer to nutrient poor soils can also produce NO_x. Ammonia (NH_4) produced by animals and from the manufacturing of fertilizers can also contribute to NO_x in the atmosphere. Through a series of chemical reactions, the nitrogen oxides are converted to nitrates which can be converted to weak nitric acid (HNO_3) when exposed to moisture in the air or on the ground.



Presently in Alberta, the single largest source of NO_x is the transportation sector, which accounts for almost 40% of the total emissions. The largest potential for reduction is within the natural gas and transportation sectors. NO_x emissions are expected to increase by 60-80% from 1980 levels by the year 2000. By using improved technology, however, it is expected that there will be little change in actual emissions entering the atmosphere compared to 1980 levels.

Transportation and movement of airborne acids

Airborne acidic pollutants do not necessarily contaminate the regions where they are produced. Vivid examples illustrating this situation include the controversial American-produced acidic pollutants coming from outdated coal-fired electrical plants. These pollutants eventually cause an increase in aquatic and soil acidity in Eastern Canada. Approximately 50% of eastern Canada's acidic deposition pollution has been linked to pollutants produced south of the border. However, it has been difficult to negotiate a solution with any credibility when Canadian-based industries are also responsible for producing considerable SO_2 and NO_x emissions; some of which ultimately end up as acidic deposition in the United States.

To further illustrate the capacity of acidic pollutants to travel large distances, one only has to take a historical look at the INCO non-ferrous smelting plant located in Sudbury, Ontario. INCO has been operating for over 75 years. In the early years of non-ferrous smelting, the ore was heated to great temperatures in open air pits. The resulting acidic emissions eventually increased the water and soil acidity of the surrounding area to the point where habitats were destroyed and entire ecosystems disappeared. The "denuded moonscape" appearance of the landscape near Sudbury is the direct result of over acidification. In response to this, a large (381 meter) superstack was erected to disperse the pollutants and to decrease the concentration of the acidic deposition in the surrounding region.

This solution, although beneficial to areas closer to the source, creates an increase in acidic deposition in areas further removed. Once the sulphur dioxide and nitrogen dioxide compounds are produced, the length of time they stay airborne and the distance they travel will determine how far they are removed from the actual source. Climatic conditions play a major role in determining the destination of acidic pollutants. Sulphates and nitrates, the precursors to acidic deposition, can generally last about four days as airborne particles. The movement of the particles is determined by wind speed and direction.

Alberta does not currently generate nor receive significant quantities of acid-forming emissions from outside of provincial or national boundaries. Any emissions that are generated within Alberta usually move north toward the Northwest Territories or eastward into Saskatchewan. As Alberta oil sands development continues to increase, there is a potential for future problems to exist as acidic pollutants move into more vulnerable areas in northeastern Alberta, the Northwest Territories, and northern Saskatchewan. Within Alberta, dry deposition from short-range, locally produced pollutants, are the major contributors of acidic deposition.

Buffering capacity

The acidic deposition situation in eastern Canada is distinct from Alberta in several ways. The first distinction is related to the volume and type of acidic deposition that falls on these regions. The second is related to the characteristics of the land on which these pollutants fall. Eastern Canada is very vulnerable to the accumulative effects of acidic deposition because the soils and lakes are not capable of neutralizing the acid. In Alberta, most regions have alkaline soils that can absorb acidic deposition without an accompanying decrease in pH values.

This capacity for the soil to act as a buffer to neutralize the acidity is important in combating the effects of acidic deposition. Eastern Canada, because of its large areas of granite and exposed bedrock, has very little natural buffering capacity and is therefore susceptible to the effects of acidic deposition.

The aquatic systems of the region have similar buffering characteristics as the soils because the sediment in the lakebeds is usually of the same composition as the surrounding land. Alberta does have some potentially vulnerable areas in the northeastern areas of the province where part of the Canadian Shield is exposed. The lakes and soils in this region do not have good buffering capacity.

Dust particles in the air can also neutralize acidic pollutants. Soils, particularly in southern Alberta, are naturally high in alkalinity. Wind movement causes some of this dust to become suspended in the atmosphere. These particles can attach themselves to acidic pollutants or they can combine with tiny water droplets to form rain. This rain, can, in some instances, have a pH greater than 5.6.

Prolonged exposure can cause a region to lose its buffering capacity. When this happens, the pH begins to decrease and the environment begins to demonstrate the effects of increased acidity. For long periods of time, there may be no evidence of acidification. Once the balance point has been reached, it takes very little time for a region to dramatically drop in pH. At this point, the environmental effects become evident.

Aquatic effects of acidic deposition

The biological, physical, and chemical characteristics of an aquatic ecosystem determine how sensitive an area is to acidic deposition. In a lake's ecosystem, acidic pollutants are deposited

directly into the lake or they reach the lake from streams and run-off that are part of the lake's watershed.

Any change to an environment can lead to a disruption of habitat and will eventually result in a noticeable change in the kinds of plants and animals there. Spring meltwater, which carries an accumulated concentration of acidic deposition, can rapidly decrease the pH of an aquatic environment. Even well buffered lakes that would normally be able to neutralize gradually increasing amounts of acidity might be unable to handle the sudden increase. This springtime *acid shock* can have serious consequences on organisms that are at vulnerable stages of their life cycle. Spawning, egg development, and invertebrate life cycles can be severely affected. Entire food webs can change when organisms at the lower end of the food chain begin to die off. Many invertebrates are unable to tolerate acidic conditions. They are also affected because there is a decrease in the amount of food available to them. As lakes become more acidic, there is also a drop in the number and type of phytoplankton. These tiny single-celled plants are at the base of the food chain in an aquatic environment and as their numbers are reduced, the entire ecosystem can be affected and food webs become simplified as entire species disappear.

Tolerance

Organisms have varying degrees of tolerance to the amount of acidity they can be exposed to. Even within the same species individual organisms may not have the same levels of tolerance. Although invertebrates and bacteria populations are the first to become affected by lower pH levels, the impact of acidic conditions is usually noticed only when vertebrate populations are reduced. Fish, frogs, salamanders, and aquatic birds also have varying degrees of tolerance to acidity. This can be the result of their physical reaction to increased acidity or due to the change in animal or plant populations on which they normally feed.

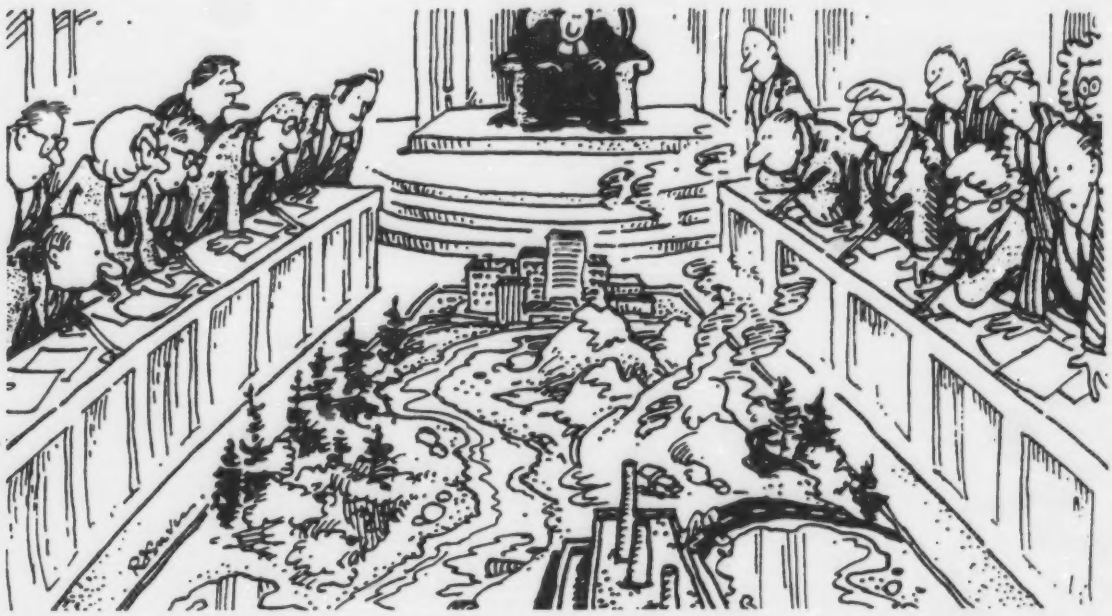
Frogs and salamanders often lay their eggs in pools of spring meltwater. These pools can be up to five times more acidic than normal conditions. If concentrations become too significant, the egg provides no protection to the developing embryos.

The size, age and type of fish are factors that contribute to how well an individual fish can tolerate acidification of its aquatic ecosystem. Generally, larger fish are able to tolerate acidic conditions better than smaller fish. The average age of a particular species of fish in a lake can indicate the age group at which the species is most susceptible. For example, lakes with a disproportionate number of older fish of a certain species indicate that the pH of the lake is reducing the survival rate of younger fish. As this continues, the species' ability to reproduce is severely affected and could ultimately result in its disappearance from the ecosystem. Any birds that are dependent upon that particular species would also be pressured to find other habitats.

Leaching of metals from soils and sediments

Increased acidity can lead to some very dramatic chemical changes within a lake ecosystem that may create intolerable conditions for the organisms living there. As the pH of a water body decreases, heavy metals that were held inert within the sediment of the lakebed are released into the aquatic environment. This leaching of soils and sediments by acidic water can raise the levels of mercury, cadmium, aluminium and other dissolved metals in the lake. This, in turn, affects the physiology of the organisms exposed to them. Leaching can also occur when acid rain percolates the soils surrounding the watershed. The water containing the metals in solution eventually enters the lake. Some metals, such as aluminium, can affect the gills of fish and contribute to respiratory failure. Other metals, such as lead and mercury, are stored in the fatty tissues or internal organs of fish as they eat plants and other organisms that have absorbed these metals. Through biomagnification, these metals make their way up to higher levels of the food chain. At this stage, the metals can have serious physiological effects on higher order organisms. Detrimental effects include higher reproductive mortality and an increase in physical deformities. Humans

can also be affected. Acidic water can promote corrosion in household plumbing. As a result, lead from the solder used to join the pipes can end up in drinking water.



Sources and Solutions

Being aware of the sources and causes of acidic deposition is only the beginning. As more public pressure is placed on these who pass legislation and on industries and individuals responsible for these sources, the amount of airborne pollutants should decrease. Currently, there are programs under way in Alberta, Eastern Canada, and between Canada and the United States to reduce emission levels. Co-operation and a willingness to take environmentally positive actions are required by all sectors of society, from private citizens to corporations, and throughout all levels of government.

Solutions are available to reduce SO_2 and NO_x emissions from the four largest contributors. Coal-fired hydroelectric plants, non-ferrous metal smelters, transportation vehicles, and sour gas refineries can reduce their total acidic emissions. In the past, the most common argument for inaction was the need to complete further studies before investing any finances into possible solutions. This argument is no longer valid and the need to take real action is taking precedence.

Coal-Fired Electrical Plants

SO_2 is the main pollutant produced by coal-fired electrical plants. These plants are located primarily in the United States and often use outdated technology. The emissions can end up as acidic deposition in Eastern Canada. The SO_2 comes from burning coal that has a high sulphur content. Anywhere from three to 60 kg of sulphur can be released into the atmosphere for every tonne of coal used as fuel. In addition to SO_2 emissions, coal-fired plants also release NO_x. Solutions to reducing emissions from this industry include:

- Retrofitting existing plants to use modern technology.
- Using coal that has a lower sulphur content.
- Removing the sulphur from the coal prior to combustion through a variety of chemical processes.
- Neutralizing the sulphur during combustion by chemical reaction with an alkaline (base) compound.
- Removing the sulphur after combustion by using scrubbers in smokestacks.

NO_x can be reduced by:

- Changing the process involved in burning the coal from a one-step to a multi-step process thereby reducing the need for extreme temperatures that would otherwise increase NO_x emissions.
- Injecting neutralizing compounds such as limestone during the combustion process.
- Removing the NO_x after combustion using scrubbers.

Non-Ferrous Smelting Industries

In Canada, these industries are the primary source of SO_2 emissions. In the smelting process, metals such as nickel, copper, lead, and zinc are separated from the rocks that contain them in a heat intensive process. The rocks containing these metals also have a very high sulphur content. This sulphur is released as a waste product during the smelting process. There is approximately a 4 to 1 ratio of sulphur released to the amount of metal recovered. These smelting industries are well established within their communities and are the major source of employment and economic stability for those areas. The Vice-President of INCO stated that, "In terms of technology, you could capture everything but you can't make a living...we all pay a little bit for the lifestyle we enjoy." As a society, we must make realistic decisions that allow us to maintain economic stability while sustaining our environment. Solutions to the reduction of SO_2 emissions in smelting operations include:

- Physically or chemically removing the sulphur from the ore before smelting.
- Using the sulphur to make products that can be used in other industries and selling these products to recover the cost of removing them from emissions.
- Using advanced technology in smokestacks to remove the sulphur emissions.

Transportation

The internal combustion engine is responsible for producing over half the total NO_x emissions in Canada. Because these emissions are the precursors to the formation of weak nitric acid (HNO_3), it is important that these emissions be reduced. NO_x emissions are also responsible for other forms of air pollution such as smog and the increase in ground-level ozone concentrations. Solutions to reducing NO_X emissions include:

- Using higher standards of emission control devices on all vehicles.
- Developing stronger legislation prohibiting the use of mis-fueling or tampering with emission control devices in vehicles.

- Developing more efficient use of public transportation.

Sour Gas Plants

Natural gas reservoirs that contain H_2S must be refined before the natural gas can be used. Technology is available to remove up to 99.9% of the sulphur that would otherwise be flared off into the atmosphere. The cost of removing sulphur increases dramatically as the removal rate approaches 100%. Some smaller refineries do not recapture the sulphur and burn off the unwanted H_2S. Larger refineries are able to remove sulphur and sell it to help offset the costs for removing it from natural gas. Many sour gas refineries in Alberta are characterized by their distinctive flare stack and the large blocks of yellow sulphur that have been produced during the refinery process that are awaiting transportation to global markets.

Personal Action

The actions of every individual contribute to the problem of acidic deposition. Similarly, environmentally responsible actions of individuals can collectively help to reduce the annual amounts of acidic deposition. Through education and a commitment to actin, individuals will learn that they too can play a role in minimizing acidic deposition. Here are a few suggestions for individual action:

☑ Conserve energy by using energy efficient appliances, shut off lights when they are not required, put flow reducers on showers, and regulate the use of furnaces and air conditioners. By reducing power and energy needs, the demand for electricity is decreased. This ultimately results in fewer pollutants entering the atmosphere from electrical power plans.

☑ Minimize the amounts of NO_x by maintaining the emission system in your vehicle and switch to alternate means of transportation whenever possible.

☑ Choose consumer products that are more environmentally friendly.

☑ Let your concerns be heard by communicating to your local member of government or to industry representatives.

CHAPTER TWO

Sources Of Acidic Deposition

Earth is the only planet in our solar system to have an atmosphere of nitrogen and oxygen. The larger planets have sufficient gravity to maintain the lighter hydrogen and helium atmospheres. Earth's smaller size allowed the lighter hydrogen and helium gases to escape into space, leaving behind the heavier nitrogen gas. The smaller Mars and Venus lost nitrogen gas, leaving behind a heavier carbon dioxide atmosphere. The smallest planet, Mercury, lost its entire atmosphere to space.

About 3.8 billion years ago, plants evolved on earth. The process of photosynthesis started, and oxygen became a part of our atmosphere. It took another 1.8 billion years before enough oxygen collected in the atmosphere to produce sufficient ozone to protect the earth from high-energy ultraviolet light.

Table 1: The most common gases in Earth's atmosphere

Name	Formula	%
Nitrogen	N_2	78
Oxygen	O_2	21
Argon	Ar	0.9
Carbon Dioxide	CO_2	0.03

Human activities have changed the concentration of trace gases in the atmosphere. Table 2 shows the major trace gases, their sources, and their approximate concentrations over time.

Table 2: Trace gases, their sources, and concentration				
Gas	Major Source	Concentration 100 years ago (*ppb*)	Concentration today (*ppb*)	Concentration in year 2003 (*ppb*)
Carbon Dioxide	Deforestation, Fossil Fuel combustion	290,000	350,000	450,000
Methane	Landfill, Cattle, Fossil Fuel Production	900	1,700	2,300
NO_x Gases	Burning of/and Fossil Fuel Combustion	0.001	0.001-50.0	0.001-50.0
Sulphur Dioxide	Ore smelting, Fossil Fuel combustion	0.03	0.03-50.0	0.03-50.0
Chlorofluoro-carbons	Aerosol sprays, Refrigerants, foams	0	3.0	2.4-6.0

As Table 2 shows, the burning of fossil fuels, deforestation, landfills, ore smelting, aerosol sprays, and the use of refrigerants are the specific human activities that are contributing to changes in the atmosphere.

Some scientists believe that the changes in concentration of carbon dioxide and methane are contributing to climate change. The carbon dioxide in the atmosphere allows energy from the sun into our atmosphere but prevents the reradiated heat from escaping. This is much like the effect of glass over a greenhouse and is called the greenhouse effect. Climate change may result in the warming of the earth, increase in the levels of the oceans as the polar ice melts, drier conditions in most of central Canada and a general movement of warmer climatic conditions northward.

One class of chemicals, the chlorofluorocarbons (CFCs), is used in aerosol cans, solvents, refrigerants and the production of insulating foams. These chemicals are relatively nonreactive at low levels in the atmosphere, but as they move into the upper atmosphere, their structure is affected by the high-energy ultraviolet light from the sun. The ultraviolet light liberates the chlorine atoms. The chlorine atoms aid in the conversion of ozone, $O_{3(g)}$, to oxygen $O_{2(g)}$.

This conversion is responsible for a decrease in the ozone concentration in the upper atmosphere. Ozone in the upper atmosphere absorbs ultraviolet light. With less ozone more ultraviolet light will reach the lower atmosphere. The short wavelengths of ultraviolet light are harmful to all forms of life.

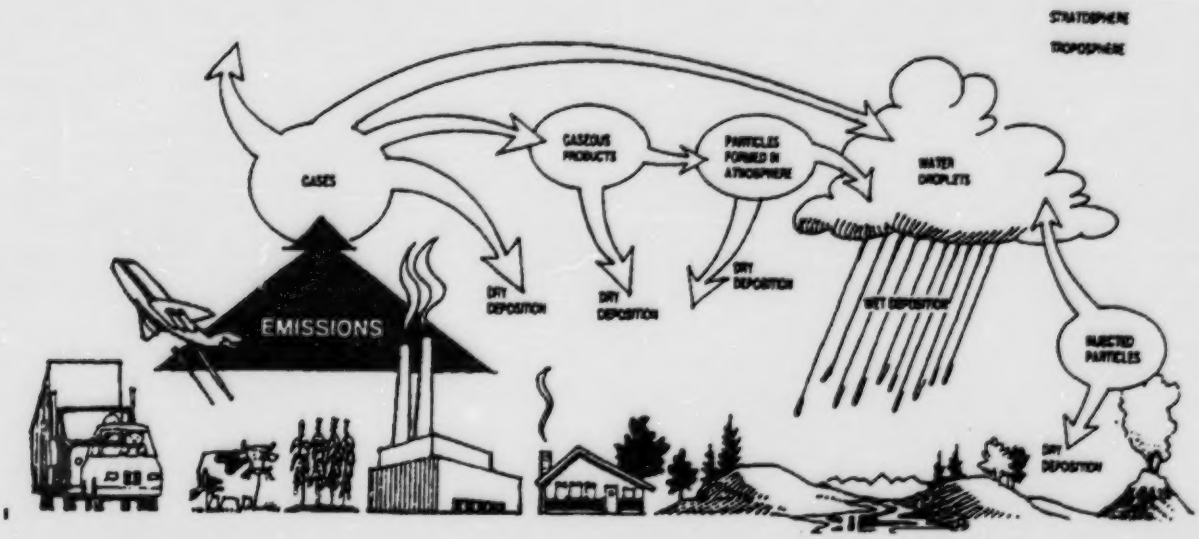


Figure 2: *Both gases and particles enter the atmosphere. The gases may be deposited on the ground either dry or in rain. The particles similarly may be deposited dry or as part of rain.*

Figure 2 shows that dissolved gases in rain are not the only source of acidic deposition; gases and particles can settle to the ground by themselves. This is called acidic deposition. "Acidic deposition" is used to describe both the acid in rain, snow and fog and the acids that are deposited by themselves without being dissolved in water. It is important that both types of deposition be measured.

WET DEPOSITION + DRY DEPOSITION = TOTAL DEPOSITION

Activity 1- What are the major sources of sulphur dioxide in Alberta?

Materials: Protractor

Analysis:

- Draw a pie graph of the data in Table 3
- What are the two major sources of sulphur dioxide in Alberta?
- What percentage is contributed by these two sources?

Table 3: Total sulphur dioxide emissions contributed by major sources

Source	Petroleum Industry	Electrical Utilities	Pulp & Paper Industry	Chemical Industry	Other
%	81.5	16.6	0.8	0.6	0.5

Observations:

The petroleum industry contributes 81.5% of all sulphur dioxide. The major activities contributing to this large contribution are:

Sour gas extraction plants:

Natural gas in some parts of Alberta contains hydrogen sulphide gas ($H_2S_{(g)}$). This gas is extremely poisonous and must be removed before the gas can be used. The hydrogen sulphide is converted into sulphur and water as shown in the following reaction:

$$8\ H_2S_{(g)} + 4O_{2(g)} \longrightarrow S_{8(g)} + 8\ H_2O_{(g)}$$

Any of the unreacted hydrogen sulphide is burned and released up the stack into the atmosphere as sulphur dioxide and water vapour. Ninety-six percent of the hydrogen sulphide is converted into solid sulphur. Only four percent of the hydrogen sulphide enters the atmosphere as sulphur dioxide. In Alberta this small percent amounts to 572.4 t/d of sulphur dioxide entering the atmosphere.

Oil Sands Plants:

The thick bitumen extracted from the tar sands in northern Alberta also contains hydrogen sulphide. The extraction of the hydrogen sulphide is accomplished in the same way as the sour gas extraction plants. The amount of sulphur dioxide entering the atmosphere, from oil sands plants is 355.8 t/d.

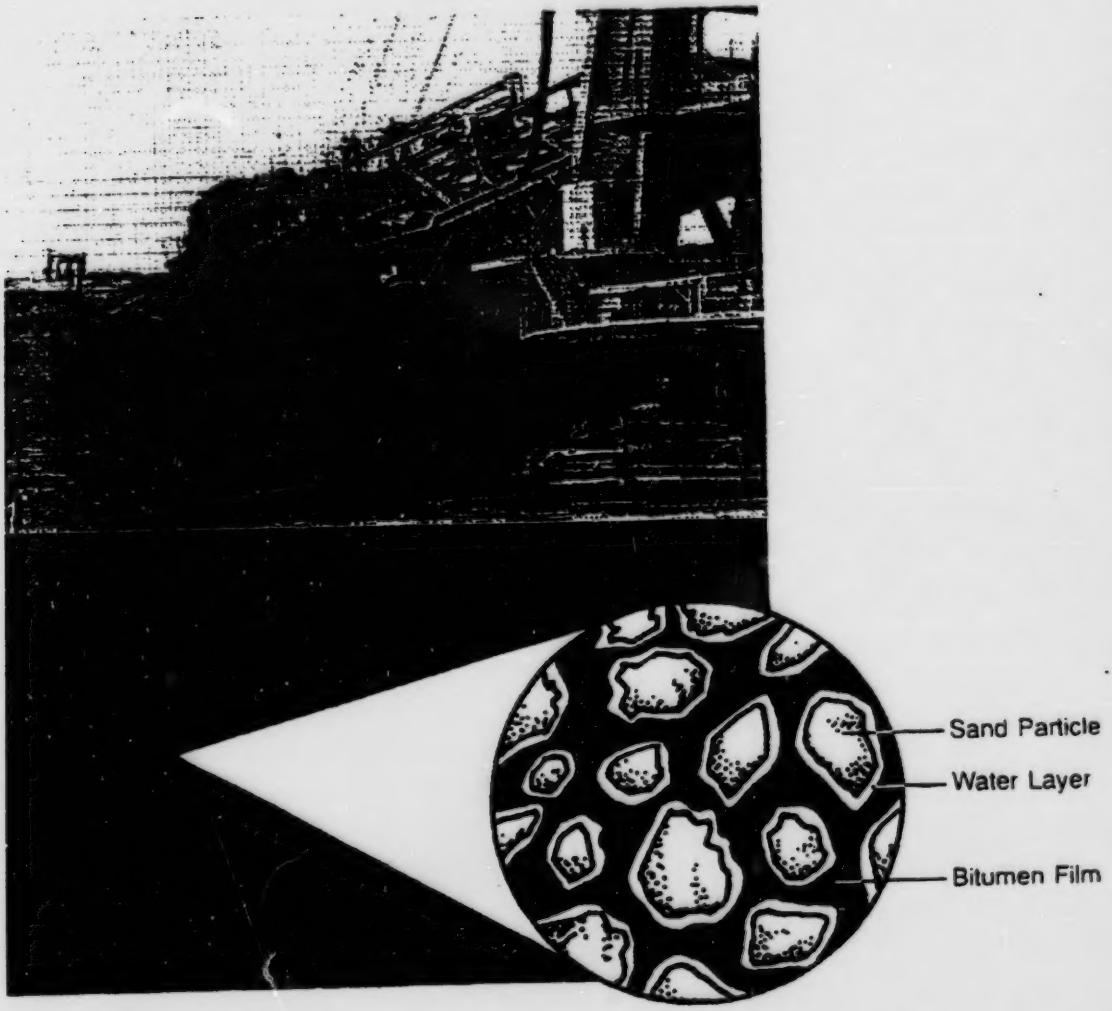


Figure 3: *The tar sands of Alberta contain a large amount of thick oil mixed with sand.*

The sour gas extraction plants and the oil sands plants account for 90% of the sulphur dioxide added to the atmosphere by the petroleum industry.

Electrical utilities contribute 16.6% of sulphur dioxide in Alberta. Alberta has a rich supply of coal with much of this coal being low in sulphur content. The electrical utility companies use coal to produce electricity. The burning of coal that contains sulphur contributes 210.6 t/d of sulphur dioxide to the atmosphere.

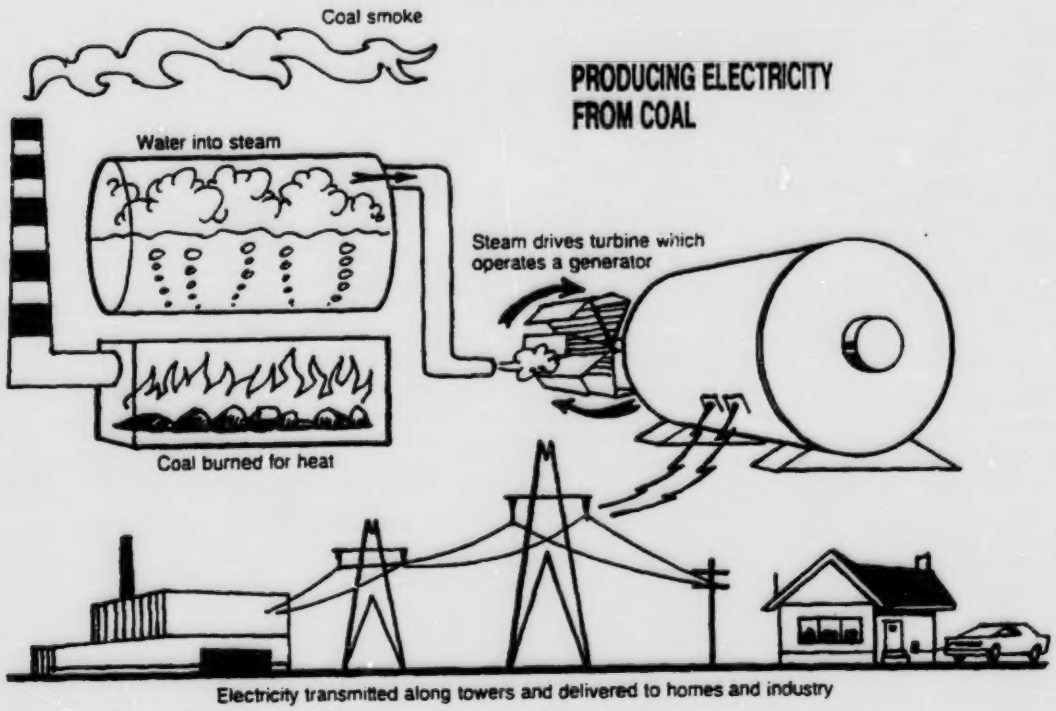

Coal smoke
PRODUCING ELECTRICITY FROM COAL
Water into steam
Steam drives turbine which operates a generator
Coal burned for heat
Electricity transmitted along towers and delivered to homes and industry

Figure 4: *The burning of coal makes a large part of the electricity produced in Alberta.*

Question:

How do you visualize 100 t/d (tonnes per day)?
A metric tonne = 1000 kg. If we estimate an average mass for a person at 60 kg, the 100 t/d would translate into:

$$\frac{\textbf{100 t x (1000 kg/t)}}{\textbf{60 kg/person}} = \textbf{1667 people/day!!}$$

The chemistry of sulphur dioxide

Sulphur dioxide gas, $SO_{2(g)}$, dissolves in water to form $SO_{2(aq)}$. $SO_{2(aq)}$ can react with water to form $H_2SO_{3(aq)}$, sulphurous acid.

$$SO_{2(aq)} + H_2O \longrightarrow H_2SO_{3(aq)}$$

Sulphur dioxide can, in the presence of oxygen, sunlight, and water vapour, be converted into sulphur trioxide. The sulphur trioxide can then react with water to produce sulphuric acid.

$$2SO_{2(aq)} + O_{2(g)} \longrightarrow 2SO_{3(g)}$$

$$SO_{3(g)} + H_2O_{(l)} \longrightarrow H_2SO_{4(aq)}$$

Analysis:

- What are the two major sources of sulphur dioxide that are produced by the petroleum industry?
- What is the amount of sulphur dioxide produced in t/d by each source?
- Write a balanced equation for:

  The reaction of hydrogen sulphide and oxygen.

  The reaction of sulphur dioxide and water.

  The reaction of sulphur dioxide and oxygen.

  The reaction of sulphur trioxide and water.

Activity 2 - What are the major sources of nitrogen oxide compounds in Alberta?

Materials: Protractor

Observations:

Table 4: The release of nitrogen oxide compounds into the atmosphere of Alberta

Source	Petroleum Industry	Electrical Industry	Highways	Urban Centres	Fertilizer Industry	Other
%	38.0	22.4	15.9	15.7	2.8	5.2

Analysis:

- Draw a pie graph of the data.
- What are the four major sources of nitrogen oxide compounds in Alberta?
- What percentage of the total is contributed by these four sources?

Compounds of nitrogen oxide are a product of high temperature combustion. The burning of fossil fuels such as coal, gasoline, natural gas, and oil release heat that changes the nitrogen in the air into nitrogen oxide compounds.

- What combustion processes in the petroleum industry may account for 257 t/d of nitrogen oxide compounds entering the atmosphere?
- What combustion processes in the electrical utilities may account for the 152 t/d of nitrogen oxide compounds?
- List as many combustion processes that occur on our highways and in urban centres that you can. These activities account for 214.5 t/d.

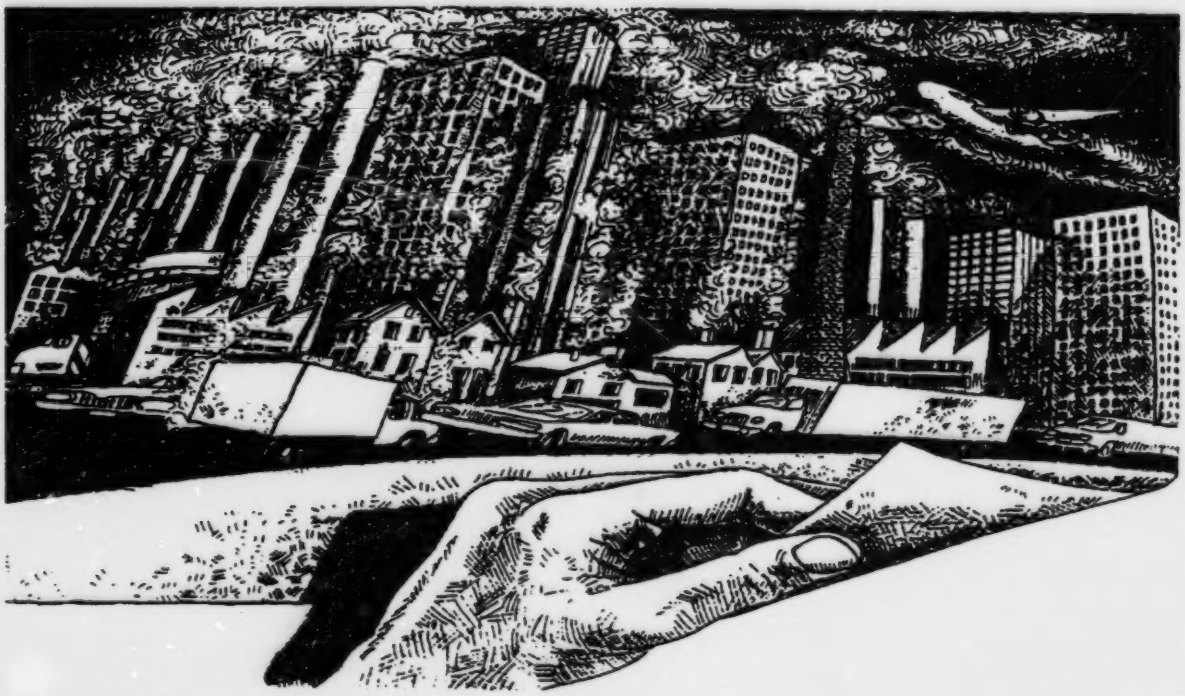


Figure 5: *The high temperatures produced by combustion produce most of the nitrogen oxide compounds in Alberta*

The chemistry of nitrogen oxide compounds

There are eight known oxides of nitrogen. The two most important in terms of our atmosphere are nitrogen oxide, $N_2O_{(g)}$ and nitrogen dioxide, $NO_{2(g)}$. Nitrogen oxide compounds are the indirect products of combustion. Some common combustion reactions are:

The burning of natural gas in a home

$$\_\_CH_{4(g)} + \_\_O_{2(g)} \longrightarrow \_\_CO_{2(g)} + \_\_H_2O_{(g)} + \text{heat}$$

And the burning of gasoline in a car

$$\_\_C_8H_{18(l)} + \_\_O_{2(g)} \longrightarrow \_\_CO_{2(g)} + \_\_H_2O_{(g)} + \text{heat}$$

The heat of combustion combines the nitrogen and oxygen in the atmosphere to produce nitrogen monoxide.

$$\_\_N_{2(g)} + \_\_O_{2(g)} + \text{heat} \longrightarrow \_\_NO_{(g)}$$

Nitrogen monoxide is highly reactive and combines with the oxygen of the atmosphere to produce nitrogen dioxide.

$$\_\_NO_{(g)} + \_\_O_{2(g)} \longrightarrow \_\_NO_{2(g)}$$

The nitrogen dioxide can now react with the water in the air to produce nitric acid and nitrous acid.

$$\_\_NO_{2(g)} + \_\_H_2O_{(l)} \longrightarrow \_\_HNO_{3(aq)} + \_\_HNO_{2(aq)}$$

Nitrogen dioxide can also react with water and oxygen to produce nitric acid.

$$\_\_NO_{2(g)} + \_\_H_2O_{(l)} + \_\_O_{2(g)} \longrightarrow \_\_HNO_{3(aq)}$$

Analysis:

All of the equations in the discussion of the chemistry of nitrogen oxide compounds are not balanced. Write the equations in your notebook and supply the correct coefficients to balance the equations.

- How is the production of sulphur dioxide different from the production of the nitrogen oxide compounds?
- What is another environmental concern that involves combustion?
- Draw the following table in your notebook and use the information in this chapter to fill in the information.

Table 5: Summary of major acid forming contributors in Alberta

	Major source in Alberta	Gases produced	How the gas is produced	Major acids produced in acid rain	Form of dry deposition
Sulphur dioxide					
Nitrogen Oxide Compound					

Activity 3 - What amounts of sulphur dioxide and nitrogen oxide compounds are produced in different regions of Alberta?

Materials:
map of Alberta similar to Figure 6

ruler

Observations:

Table 6: Tonnes of sulphur dioxide and nitrogen oxide compounds produced per day in different regions of Alberta

Region of Alberta	Sulphur dioxide (t/d)	Nitrogen oxide compounds (t/d)
1	19.8	3.4
2	0.0	0.0
3	10.1	6.3
4	355.8	29.7
5	58.3	43.2
6	0.6	20.0
7	319.5	174.1
8	50.0	124.9
9	390.5	180.0
10	62.4	96.6

Analysis:

1. Using a reasonable scale create a histogram of the data on a copy of figure 6 showing the 10 regions of Alberta.

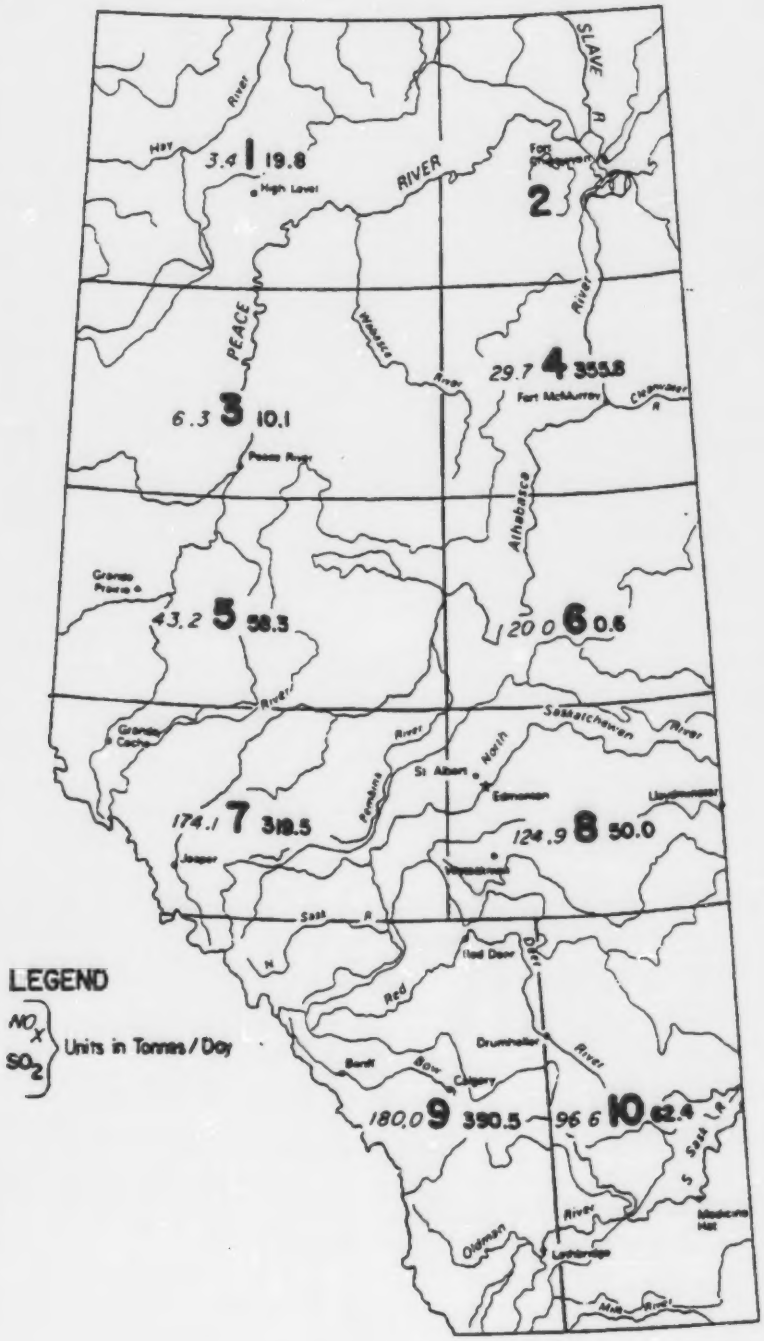


Figure 6: *Map of Alberta showing total nitrogen oxide compounds and total sulphur dioxide emissions in 10 regions of Alberta*

- What region of Alberta produces the largest amount of sulphur dioxide per day?
- What region of Alberta produces the largest amount of nitrogen oxide compounds per day?

Select your region of Alberta and list the sources of both:

- Sulphur dioxide
- Nitrogen oxide compounds

Using your knowledge of the sources of acidic deposition, hypothesize why region 4 in Alberta is so high in sulphur dioxide production and relatively low in nitrogen oxide compounds?

Activity 4 - What amounts of sulphur dioxide and nitrogen oxide compounds are produced in different parts of Canada?

Materials:

- graph
- ruler

Observations:

Table 7: A comparison of sulphur dioxide and nitrogen oxide compounds entering the atmosphere in Canada. (1000 metric tonnes)

Province	SO_2	NO_x
Alberta	462.5	247.5
Ontario	1830.6	536.5
Quebec	1157.9	331.4
Manitoba	489.9	78.1
British Columbia	192.9	199.0
Saskatchewan	57.8	148.3

Analysis:

- Draw a bar graph of the data
- Based on the information in the graph and the ideas in this chapter, make four conclusions about acidic deposition in Canada.

Monitoring Changes in the Environment

Technology uses science to monitor changes in the environment. To understand the nature of environmental problems, it is necessary to understand the science that is used in monitoring changes. This activity looks at a method to determine the amount of acid in a solution. The ideas for the activity are produced by the science of chemistry. This activity looks at the science involved in titration. You will apply the ideas and techniques you have learned to determine the amount of acid in a solution.

The Science of Titration:

Chemistry uses the unit called a mole to measure the number of things. A mole is equal to 6.0 x 10^{23} things. Concentration is measured as the number of moles of a substance dissolved in 1 L of water. Your acid-based titration will involve the adding of $N_aOH_{(aq)}$ from a Buret tube into an acidic solution contained in an Erlenmeyer flask. The solution in the Buret tube is added drop by drop until all of the acid in the Erlenmeyer flask has reacted. A chemical indicator is added to the Erlenmeyer flask to let you know when all the acid has reacted. The neutralization reaction that will occur is:

$$N_aOH_{(aq)} + \text{Acid} \longrightarrow H_2O_{(l)} + \text{A salt}$$

The reaction has a mole ratio of 1:1 between the hydrogen ion, $H^+(aq)$, in the acid and the hydroxide ion, $OH_{(aq)}$ from the $N_aOH_{(aq)}$. This tells us that one mole of the $N_aOH_{(aq)}$ used will react with exactly one mole of the hydrogen ion in the rain water.

$$OH_{(aq)} + H^+_{(aq)} \longrightarrow 2H_2O_{(aq)}$$

By using a known concentration of $N_aOH_{(aq)}$ and determining the volume of $N_aOH_{(aq)}$ needed to neutralize a known volume of acid, we can determine the concentration of the $H^+_{(aq)}$ in the acid. From this we can determine the pH of the solution.

Activity 5 - How is the pH of an acid determined by titration?

Materials:

- Buret tube
- small funnel
- Buret tube clamp
- 10.0 mL pipet
- pipet bulb
- household vinegar or rain sample
- 50 mL Erlenmeyer Flask
- 100 mL of 0.10 mol/L $N_aOH_{(aq)}$
- dropper bottle of phenolphthalein
- lap apron

Figure 7: Draw a diagram of how the equipment for a titration is assembled.

Procedure:

Set up the apparatus as shown in figure 7.

- Use the small funnel to add the $N_aOH_{(aq)}$ to the Buret tube. The Buret tube does not need to be filled to the top since you can determine the amount of $N_aOH_{(aq)}$ used with any initial reading.

CAUTION: IF YOU GET THE $N_aOH_{(aq)}$ ON YOUR HANDS WASH IT OFF UNDER RUNNING WATER FOR 1 MINUTE.

- Record the initial volume of the $N_aOH_{(aq)}$ in the Buret tube. Use a table similar to Table IX to record your data.
- Use the pipet bulb to pipet 10.0 mL of the acid rain solution into a clean 150mL Erlenmeyer flask.
- Add five drops of the phenolphthalein into the Erlenmeyer flask.
- Slowly add drops of the $N_aOH_{(aq)}$ into the Erlenmeyer as your partner swirls the solution.

- Continue to add drops of $N_aOH_{(aq)}$ until the acid solution ***remains*** a light pink colour.
- Record the final volume of the $N_aOH_{(aq)}$ on your table of observations.
- Repeat the titration for a total of three acid samples.

Observations:

Table 8: Volume of 0.10 mol/L $N_aOH_{(aq)}$ used to titrate 10.0 mL of acid rain			
Trial	Initial Buret reading (mL)	Final Buret reading (mL)	Volume Used (mL)
1			
2			
3			
Final Colour			
Average used			

Analysis:

(Note: If you are not sure about the method of calculation, study the sample solution to a titration problem starting on page 29.)

- Determine the pH of the acid of the rain sample.
- If the solution that was used in this activity was household vinegar you can assume that the concentration is 0.88mol/L. Use this value to determine your percent error in this activity.
- Use a calculator to determine the pH of your rain sample.

$$\text{Percent error} = \frac{\text{Expected value} - \text{Experimental value}}{\text{Expected value}} \times 100$$

You can extend your understanding of this technique by measuring the pH of rain samples that you collect. If it is winter it may be interesting to determine the pH of snow samples. The expected value for rain is pH of 5.6.

- Why will this technique not account for the dry deposition of acid?
- Fill in the calculated values in the following table.

Table 9: Determining the pH of a rain sample			
mL of 0.1 mol/L $N_aOH_{(ag)}$ used in titration	Volume of rain water used (mL)	Concentration of hydrogen ion (mol/L)	pH of the rain water
12.8	10.0		
8.0	10.0		
11.7	6.9		

Sample Solution To A Titration Problem:

The method shown below assumes that you have not studied calculations involving titrations. If you have studied these ideas in class you should use the method recommended by your teacher. A student obtained the following results in this activity.

Table 10: Sample data of the volume of 0.10 mol/L $N_aOH_{(ag)}$ used to titrate 10.0 mL of acid rain			
Trial	Initial Buret Volume (mL)	Final Buret Volume (mL)	Volume used (mL)
1	0.9	12.0	11.2
2	12.0	22.1	10.1
3	22.1	32.3	10.2
Final Colour	Dark Pink	Light Pink	Light Pink
Average volume Used			10.2

In determining the average volume of $N_aOH_{(ag)}$ used, the student decided to ignore the first titration in the data. Frequently the first titration exceeds the amount required to create a light pink colour. The other two trials had a lighter pink and therefore the student assumed that he volumes were more accurate.

STEP ONE:

AVERAGE VOLUME OF $N_aOH_{(ag)}$ USED = 10.2 mL

STEP TWO:

To determine the concentration of the hydrogen ion multiply the average volume (mL) of $N_aOH_{(ag)}$ used in the titration by 0.10 mol/L and divide the answer by the volume (mL) of acid rain.

$$\textbf{CONCENTRATION OF HYDROGEN ION} = 0.10 \frac{\text{mol}}{\text{L}} \left(\frac{\text{mL of } N_aOH \text{ used}}{\text{mL of acid rain}} \right)$$

For the sample problem the calculation is 10.2 mL of $N_aOH_{(ag)}$ used times 0.10 mol/L divided by 10.0 mL of acid rain per sample.

$$0.01 \frac{\text{mol}}{\text{L}} \left(\frac{10.2 \text{ mL}}{10.0 \text{ mL}} \right) = 0.102 \frac{\text{mol}}{\text{L}}$$

You can use a calculator to change the concentration of hydrogen ion into pH.

Enter the concentration of the hydrogen ion into the calculator. (0.102)

Press LOG. (-.9913998282)

Press the +/- key to change the sign. (+.9913998282)

Round the answer to two decimal places. (0.99)

$$\text{pH} = -\log[\text{hydrogen concentration}]$$

$$\text{pH} = -\log \left(0.102 \frac{\text{mol}}{\text{L}}\right)$$

$$\text{pH} = 0.99$$

CHAPTER THREE

Buffering Capacity

Buffers are chemical systems that resist changes in pH. When one adds an acid to a solution, the pH will normally decrease. However, if the solution contains a buffering system the pH will remain relatively constant for a period of time. If one were to add a base to a solution, the pH should increase. A buffering system resists changes in pH. Natural buffering systems are important to understand as we continue our study of acidic deposition.

Demonstration 1- What is an indicator?

Materials:

- 100mL of 0.1 mol/L HCl
- eight Petri dishes
- 100 mL of 0.1 mol/L NaOH
- distilled water
- eye dropper
- dropper bottle of phenolphthalein indicator solution
- pipet bulb 1.0 mL pipet
- 10.0 mL graduated cylinder
- overhead projector

Procedure: Demonstration of the colour changes of indicators

Use a felt pen to mark the following concentrations on the outside, bottom of eight Petri dishes.

0.1 mol/L $NaOH_{(aq)}$	0.1 mol/L $HCl_{(aq)}$
0.01mol/L $NaOH_{(aq)}$	0.01 mol/L $HCl_{(aq)}$
0.001 mol/L $NaOH_{(aq)}$	0.001 mol/L $HCl_{(aq)}$
0.0001 mol/L $NaOH_{(aq)}$	0.0001 mol/L $HCl_{(aq)}$

- Add about 10.0 mL of the 0.1 mol/L $NaOH_{(aq)}$ into a Petri dish. The pH of this solution should be about 13.
- Add 1.0 mL of the 0.1 mol/L $NaOH_{(aq)}$ to a second Petri dish. Add 9 mL of distilled water to the second Petri dish. The concentration of the $NaOH_{(aq)}$ is now 0.01 mol/L.
- Add 1.0 mL of the diluted solution in the second Petri dish to a third Petri dish. Add 9 mL of distilled water to the third Petri dish. The concentration of the $NaOH_{(aq)}$ is now 0.001 mol/L.
- Dilute the solution in the third Petri dish to create a concentration of 0.0001 mol/L of $NaOH_{(aq)}$.
- Starting with a 0.1 mol/L solution of $HCl_{(aq)}$ use steps 2-5 to create Petri dishes containing 0.01 mol/L, 0.001 mol/L, and 0.0001 mol/L solution of $HCl_{(aq)}$.
- Arrange the Petri dishes on the overhead and add five drops of indicator to each.

Figure 7: What is the colour of the indicator in each of the Petri dishes?

Analysis:

Use a table similar to Table 11 to record your data.

Table 11: Colour of an indicator at different pH values

Concentration & substance	pH	Colour of Indicator
0.1 mol/L NaOH	13	
0.01 mol/L NaOH	12	
0.001 mol/L NaOH	10	
0.0001 mol/L NaOH	9	
0.0001 mol/L HCl	4	
0.001 mol/L HCl	3	
0.01 mol/L HCl	2	
0.1 mol/L HCl	1	

- What is the colour of phenolphthalein in a solution with an acid pH?
- What is the colour of phenolphthalein in a solution with a basic pH?

Demonstration 2 - What is a buffer?

Materials:

- two Petri dishes distilled water
- 0.1 mol/L $NaOH_{(aq)}$
- prepared buffer solution of pH7*
- dropper bottle of phenolphthalein indicator
- 0.1 mol/L $HCl_{(aq)}$

* Note: You can make this solution by adding 122.0 mL of 15 mol/L $Na_2HPO_{4(aq)}$ to 78.0 mL of 15 mol/L $KH_2PO_{4(aq)}$

Procedure:

- Use a felt marker to label the outside bottom of a Petri dish with "Buffer". Add to this Petri dish 20 mL of the buffer solution.
- Use a felt marker to label the outside bottom of a Petri dish with "No Buffer". Add to this Petri dish 20mL of distilled water. Both Petri dishes are at pH7.
- Place both Petri dishes on the overhead projector. Add 30 drops of indicator to each of the Petri dishes.
- On a table similar to this one below, record the number of drops of 0.1 mol/L $NaOH_{(aq)}$ that are added to each of the Petri dishes to change the colour pink. Stir the solution as you add the $NaOH_{(aq)}$.
- On a table similar to this one below, record the number of drops of 0.1 mol/L $HCl_{(aq)}$ that are added to each of the Petri dishes to change the colour back to clear.

Observations:

Table 12: The effects of a buffer

Solution	Number of drops of $NaOH_{(aq)}$ added to change colour to pink	Number of drops of $HCl_{(aq)}$ added to change colour to clear
Buffer Solution		
Distilled water		

Analysis:

- Which solution required more $NaOH_{(aq)}$ to change colour?
- Which solution required more $HCl_{(aq)}$ to change colour?
- What does a buffer do?

Buffers are important types of solutions. They help to maintain a constant pH. To understand the nature of buffers we will need to look more closely at the nature of the reactions. A buffer consists of a weak acid and its conjugate base. In our example, the weak acid $H_2PO_4^-{}_{(aq)}$ is produced when $KH_2PO_{4(aq)}$ dissociates in water.

$$KH_2PO_{4(aq)} \longrightarrow K^+_{(aq)} + H_2PO_4^-{}_{(aq)}$$

The conjugate base $HPO_4^{2-}{}_{(aq)}$ is produced when the $Na_2HPO_{4(aq)}$ dissociates in water.

$$Na_2HPO_{4(aq)} \longrightarrow Na^+_{(aq)} + HPO_4^{2-}{}_{(aq)}$$

We now have a chemical system that can respond to any attempt to change pH. If we add a base to this system the following reaction will remove the $OH^-_{(aq)}$. As a result the pH will remain the same until all of the $HPO_4^-{}_{(aq)}$ is used up.

$$OH^-_{(aq)} + H_2PO_4^-{}_{(aq)} \longrightarrow H_2O_{(l)} + HPO_4^{2-}{}_{(aq)}$$

If one adds an acid to this system the following reaction will remove the $H^+_{(aq)}$ and as a result the pH will remain the same until the $HPO_4^{2-}{}_{(aq)}$ is used up.

$$H^+_{(aq)} + HPO_4^{2-}{}_{(aq)} \longrightarrow H_2PO_4^-{}_{(aq)}$$

A buffer system can respond to either the addition of acid or base and maintain a constant pH until the system runs out of one of the reactants.

Activity 6 - Does soil contain a natural buffer system?

Materials:

- eye droppers or microchemistry pipet
- universal pH paper or pH meter
- 100mL graduated cylinder
- 100 mL Erlenmeyer flask
- stopper for 100 mL Erlenmeyer flask
- two Petri dishes or microchemistry plates
- dropper bottle of orange IV indicator or any other indicator that changes colour in the lower acid region
- filter paper
- small funnel
- soil sample
- dropper bottle of 0.1 mol/L $NaOH_{(aq)}$
- dropper bottle of 0.1 mol/L $HCl_{(aq)}$

Procedure:

- Add 20 mL of soil to the Erlenmeyer flask. Fill to the 100 mL point with distilled water. Stopper the Erlenmeyer and shake vigorously for five minutes.
- Filter the soil extract and save the water, in a Petri dish, to use in your analysis.
- Determine the initial pH of the soil water using universal pH paper or a pH meter.
- Add about the same volume of distilled water to a different Petri dish. Adjust the pH of the distilled water, using the $NaOH_{(aq)}$ to raise the pH or the $HCI_{(aq)}$ to lower the pH, to the same value as the soil water.
- Orange IV is an indicator that is red below a pH of 1.4 and is yellow above pH 2.8. Count the number of drops of $HCI_{(aq)}$ that you need to add to the solution to change the colour from yellow to red. Use a table similar to Table 13 to record your results.

Observations:

Table 13: A comparison of distilled water and soil water for changes in pH

Solution	Number of drops of 0.1 mol/L $HCI_{(aq)}$ added to change the colour from yellow to red
Distilled water	
Soil water	

Analysis:

- Does the soil water contain a buffer system that resists changes in pH? Explain your answer.
- Why was the pH of the distilled water made the same before the addition of the acid?
- Do you think all soils have the same ability to resist changes in pH? Explain your answer.

Activity 7 - How do soils vary in the response to changes in pH?

Soil is a complex chemical and biological system. The response of soil to the addition of an acid depends on a number of factors.

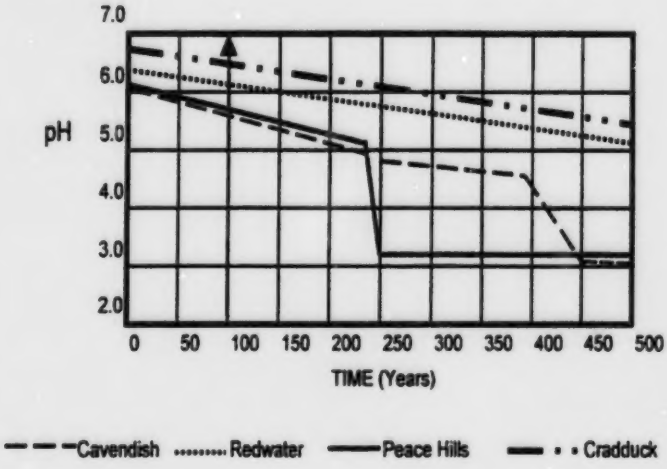
Soils contain chemicals that can neutralize the addition of acids. A neutralization reaction removes the $H^+_{(aq)}$ ion from the solution by combining it with a base. There are about 25 common reactions that can occur between the $H^+_{(aq)}$ and common bases that may appear in the soil. The type of soil determines many of the reactions that occur. Soils can be classified

according to how they respond to the addition of acid. Scientists often construct models to deal with complex situations where many factors interact.

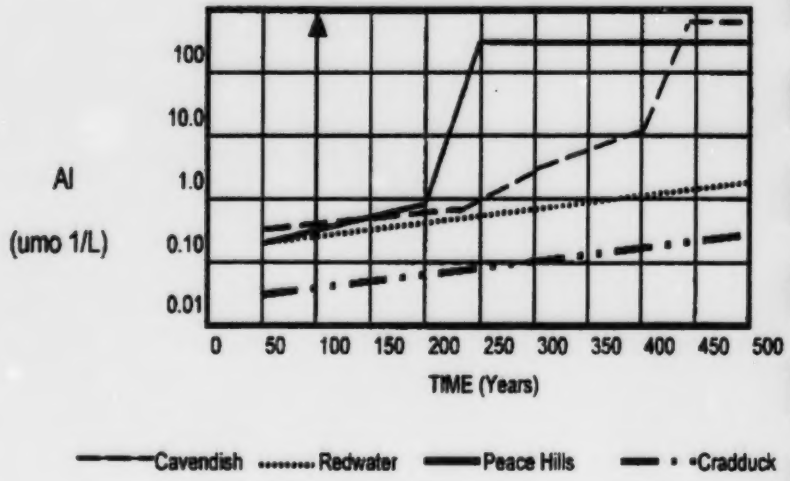
The data that you will analyze in activity seven is the product of a model that attempts to predict the effect that acid will have on two different Alberta soils. The model predicts the change of soil pH with the addition of 0.1kmol of $H^+_{(aq)}$ per hectare per year. Also included is the effect of the change in soil pH on the release of aluminium ions. Since aluminium ions are toxic to plants, this information is of importance. It should be understood that all models are based on simplification, assumptions, and limitations. However, the construction and refinement of models helps in the understanding of complex interactions.

Observations:

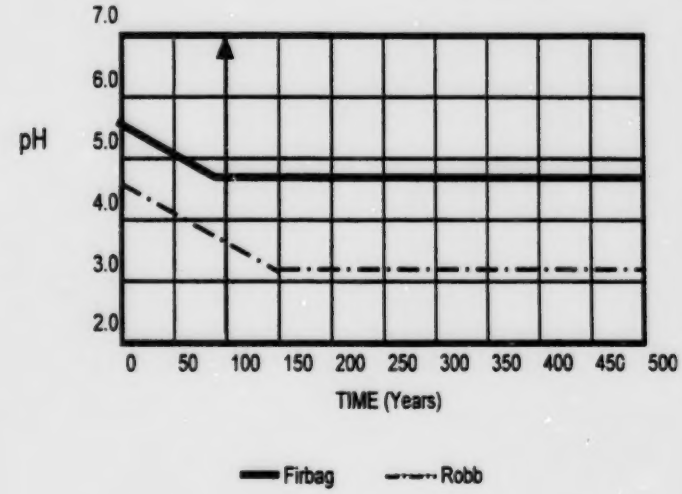
Graph 1: Model predictions for pH changes in four chernozemic soils having acid deposition of 1.0 kmol of $H^+_{(aq)}$ per hectare per year.



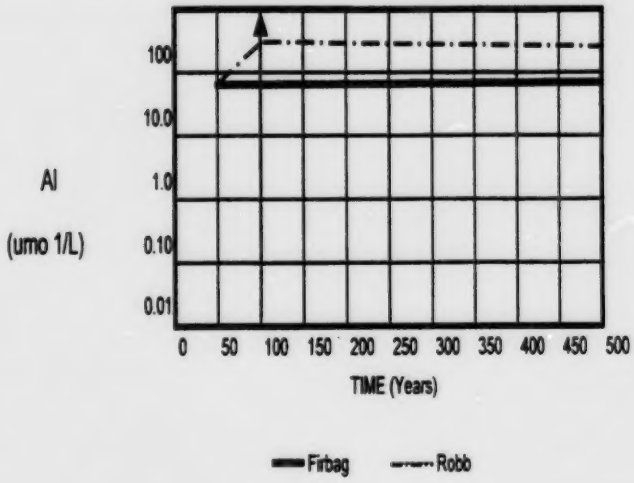
Graph 2: Model predictions for change in Al ion concentrations in four chernozemic soils having acid deposition of approximately 1.0 kmol of $H^+_{(aq)}$ per hectare per year.



Graph 3: Model predictions for pH change in two brunisolic soils having acid deposition inputs of 1.0 kmol per hectare per year.



Graph 4: Model predictions for change in solution Al ion concentrations in two brunisolic soils having acid deposition inputs of approximately 1.0 kmol per hectare per year



Analysis:

Use a table similar to the one below to compare the two types of soils. Answer the questions on the following page.

Table 14: Comparing the pH sensitivity of various soils

	CHERNOZEMIC SOIL	BRUNISOLIC SOIL
Average pH at zero years	Cradduck = Cavendish = Peace Hills = Redwater =	Firbag = Robb =
Average pH at 100 years	Cradduck = Cavendish = Peace Hills = Redwater =	Firbag = Robb =
Change in pH	Cradduck = Cavendish = Peace Hills = Redwater =	Firbag = Robb =
Average Al ion Concentration at 50 years	Cradduck = Cavendish = Peace Hills = Redwater =	Firbag = Robb =
Average Al ion concentration at 100 years	Cradduck = Cavendish = Peace Hills = Redwater =	Firbag = Robb =
Change in Al ion concentration	Cradduck = Cavendish = Peace Hills = Redwater =	Firbag = Robb =

List the six soils, in order, from the least sensitive to the most sensitive in their response to the addition of $H^+_{(aq)}$.
List the six soils, in order, from the soil releasing the lowest concentration of Al ions to the soil releasing the largest concentration of Al ions.

What value is there to classifying how soils respond to changes in the addition of $H^+_{(aq)}$?

What value is there to classifying how soils will release Al ions with changes in pH?

Activity 8 - Does a lake or river water contain a natural buffer system?

Materials:

- universal pH paper or pH meter
- two Petri dishes or microchemistry plate
- eye droppers or microchemistry pipet
- small funnel
- natural water sample (lake, stream, or tap water)
- dropper bottle of orange IV indicator or any other indicator that changes colour in the lower acid region
- 100 mL graduated cylinder
- dropper bottle of 0.1 mol/L $NaOH_{(aq)}$
- filter paper
- dropper bottle of 0.1 mol/L $HCl_{(aq)}$

Procedure:

- Add about 20 mL of the natural water sample to a Petri dish.
- Determine the initial pH of natural water sample using universal pH paper or pH meter.
- Add about the same volume of distilled water to a different Petri dish. Adjust the pH of the distilled water (using the $NaOH_{(aq)}$ to raise the pH or the $HCl_{(aq)}$ to lower the pH) to the same value as the natural water sample.
- Orange IV is an indicator that is red below a pH of 1.4 and is yellow above pH 2.8. Count the number of drops of $HCl_{(aq)}$ that you need to add to the solutions to change the colour from yellow to red. Use a table similar to Table 15 to record your results.

Observations:

Table 15: A comparison of distilled water and soil water for changes in pH

Solution	Number of drops of 0.1 mol/L $HCl_{(aq)}$ added to change the colour from yellow to red.
Natural water sample	
Soil	

Analysis:

- Does the natural water sample contain a buffer system that resists changes in pH? Explain your answer.
- Why was the pH of the distilled water made the same before the addition of the acid?
- Do you think all water samples have the same ability to resist changes in pH? Explain your answer.
- If a lake is acidic what could you add to raise the pH of the water?

Activity 9 - What is the relationship between locations of acidic deposition, sensitivity of soil, and sensitivity of water in Alberta?

Observations:

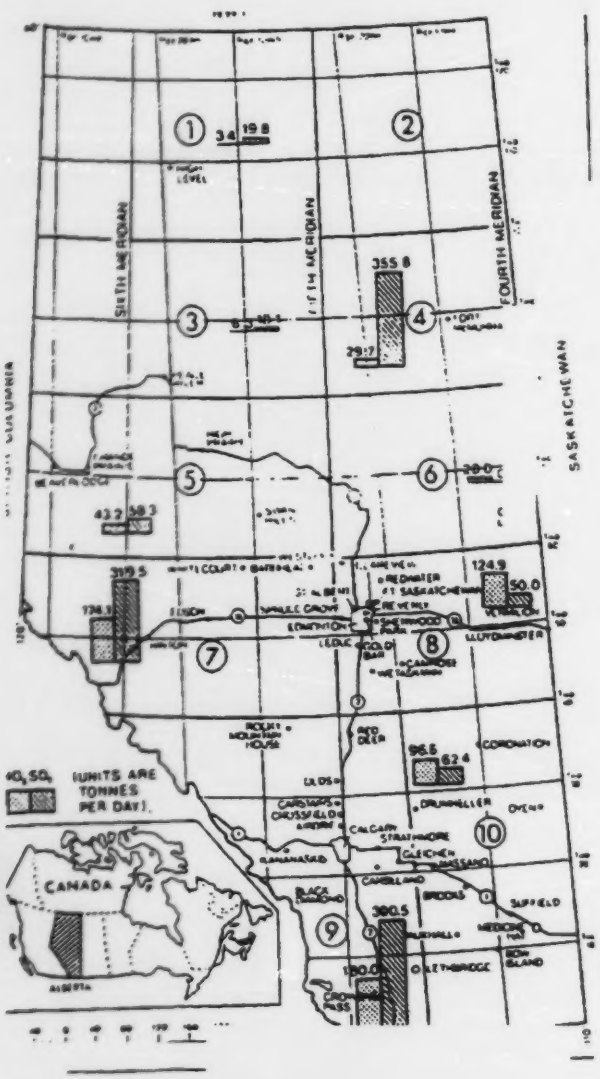


Figure 8: *Map of Alberta showing total NO_x and SO_2 emissions as histograms in each of the ten geographic regions.*

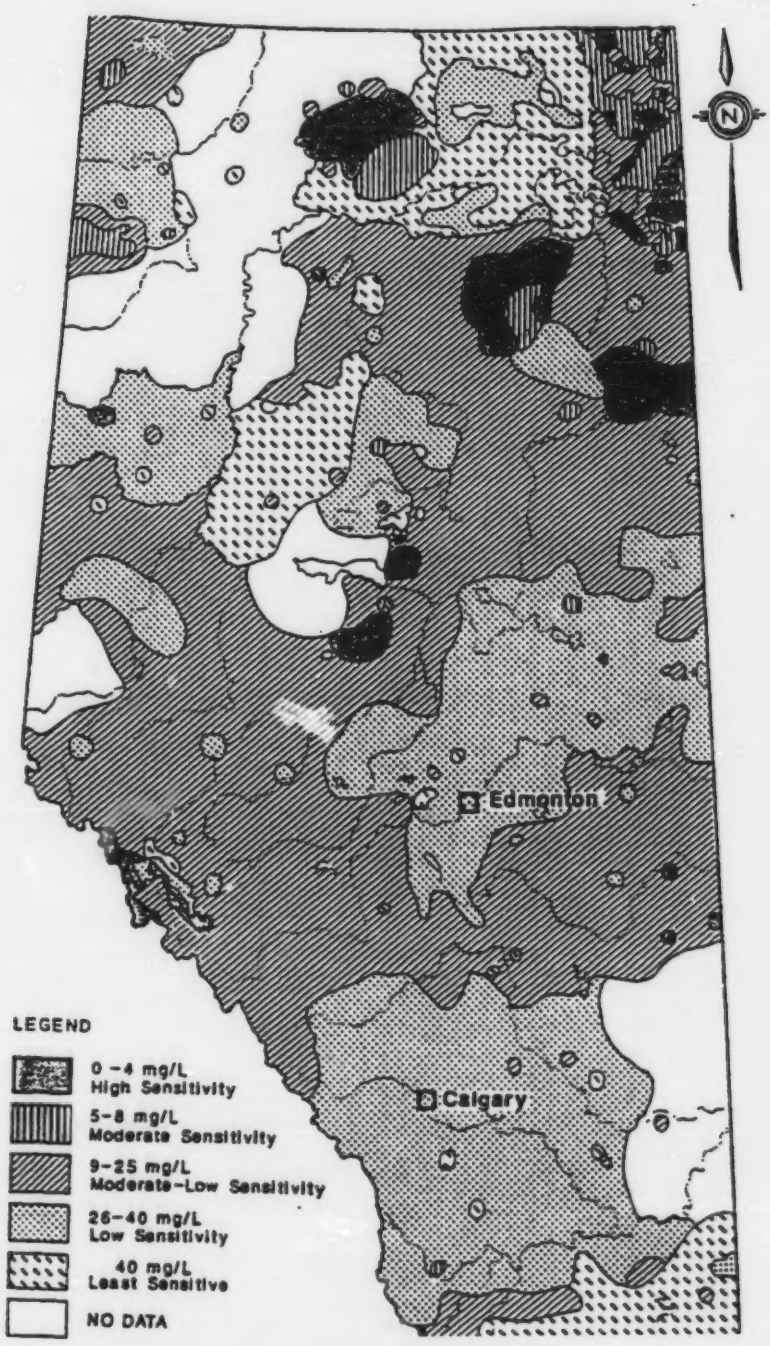


Figure 9: *Sensitivity of Alberta lakes to acidification as determined by calcium values.*

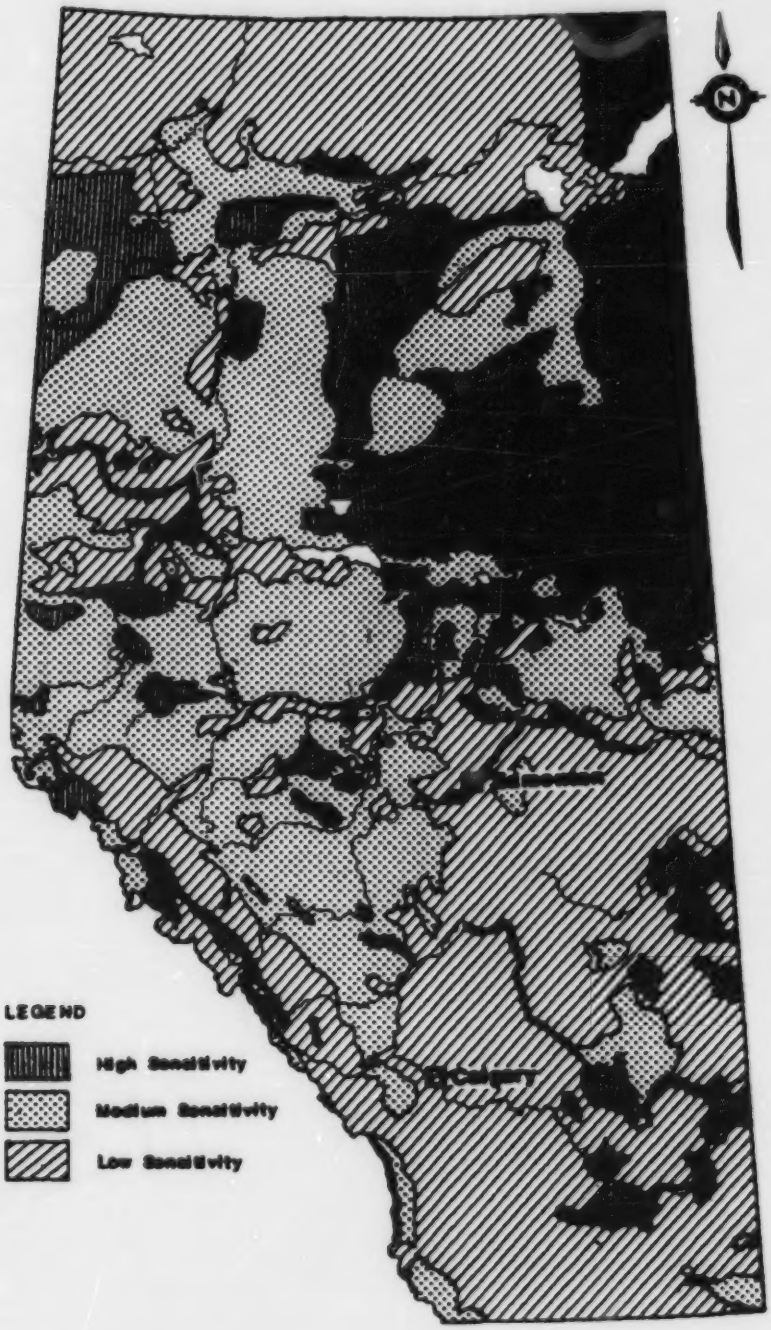


Figure 10: *Sensitivity of Alberta soils to acidification.*

Analysis:

Use a table similar to the one below to evaluate the risks to each of the areas of Alberta to acidic deposition.

Table 16: Comparing Alberta regions to acid sensitivity

Region	SO_2 produced (t/d)	NO_x produced (t/d)	Most lakes are high, medium or low sensitive	Most soil is high, medium, or low sensitive
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

- Can you design a better way to determine the degree of sensitivity of the soil and the lakes in each of the regions?
- What regions of Alberta are at the greatest risk from acidic deposition? Explain your answer.
- How would you evaluate the risk from acidic deposition in your area of Alberta?

CHAPTER FOUR

The Effects Of Acidic Deposition

In the study of any issue, it is necessary to look at the problem from many different points of view. In this chapter you will look at the effect that acidic deposition has on living things. The following activity examines the effects simulated acid rain has on plant growth. We will then look at how chemistry is important in understanding the effects that acidic deposition has on living organisms.

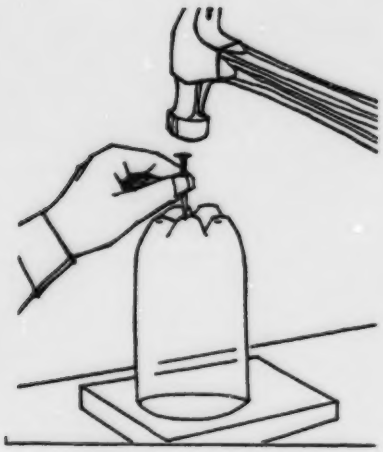
Problem 1 - What is the effect of simulated acid rain on plant growth?

Materials:

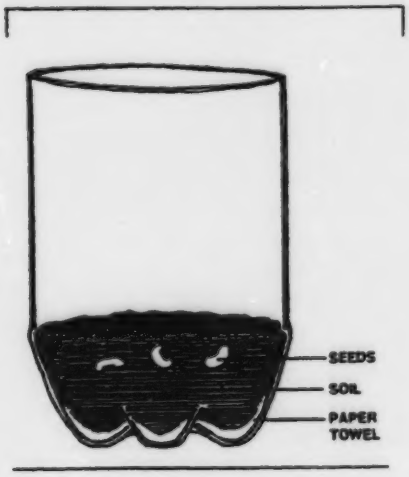
Enough material for one classroom demonstration or activity:

- eight 2.0 L plastic pop bottles
- soil
- small block of wood
- 4.0 L solution with pH 4
- 5 cm nail
- hammer
- 20 cm nail
- 20-30 bean seeds
- 4.0 L of solution with pH 2
- 4.0 L solution with pH 6
- 4.0 L of tap water
- scissors, scalpel or sharp knife

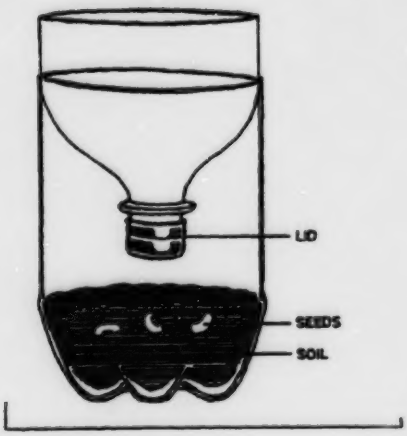
Procedure:

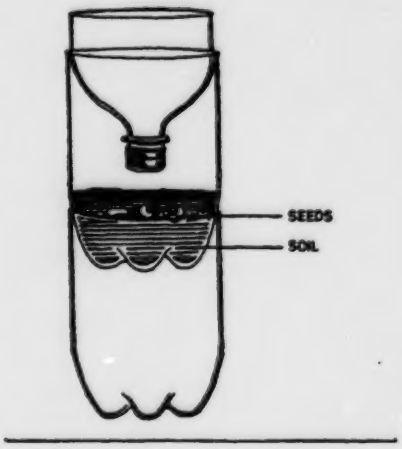


Step 1: Cut the tops off both of the bottles	**Step 2:** Use the large nail to punch holes in the bottom of one of the bottles.



Step 3: Cover the holes with a paper towel. Add soil and three bean seeds to the bottle.	**Step 4:** Using the small nail punch four holes in the lid of the pop bottle.





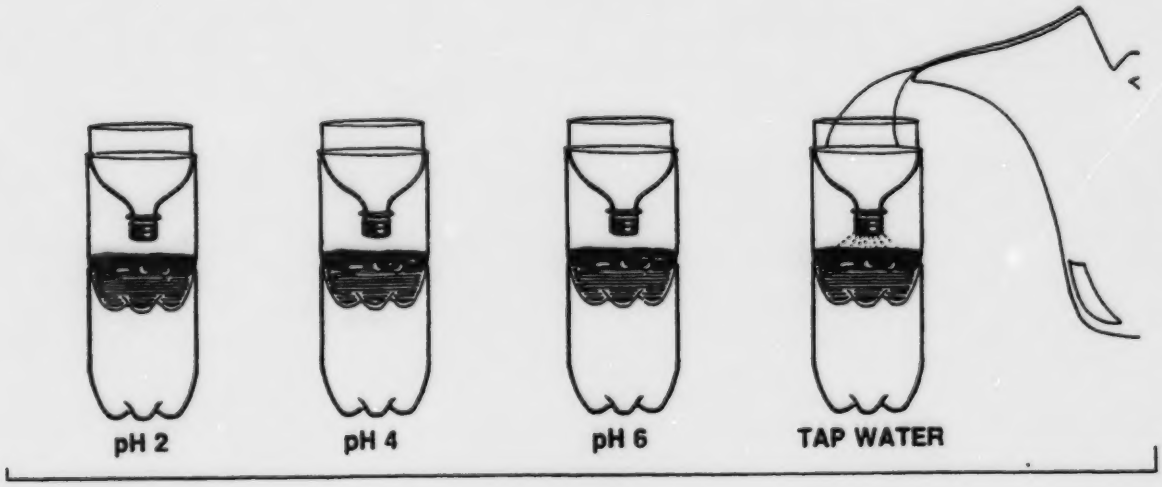
Step 5: Put the top on one of the bottle lids and invert over the bottle containing the soil.	**Step 6:** Put the bottle containing the soil into the bottom of the bottle without soil.

How to make a growth chamber.

You will need to make four growth chambers. One for each of: pH 2, pH 4, pH 6 and the tap water.

Mark each of the growth chambers with the pH values.

Place the growth chambers close to a classroom window.



Step 7: Water the plants with the appropriate solution every three days.

Observations:

Use a table similar to the one below to record your results.

Table 17: Observation of plant sensitivity to various pH levels

Date	Water added (ml)	pH 2	pH 4	pH 6	Tap water
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					

Some generalizations researchers have made about the effect of pH on agricultural plants are:

- No inhibition of growth occurs above a pH of 4.0
- Damage to leaves and crop yield occurs at or below a pH of 3.0 to 3.5
- Below a pH of 2.5, 70% of agricultural plants show some signs of damage
- Some plants are more sensitive to changes in pH than others
- Acidic deposition reduces the rate of photosynthesis in plants

Analysis:

- List each of the generalizations. Decide if your experiment supports the generalization or not. Describe how you would change the experiment to more directly confirm or deny the generalization.
- From your investigation, what generalization can you make about the effects of acidic deposition on plant growth?
- Growth of forest ecosystems in various parts of the world are affected by acidic deposition. The major reason for the decline of these forests is hypothesized to be chemical changes in the soil due to acidification.

Problem 2 - What is the effect of pH on the availability of soil nutrients?

Observations:

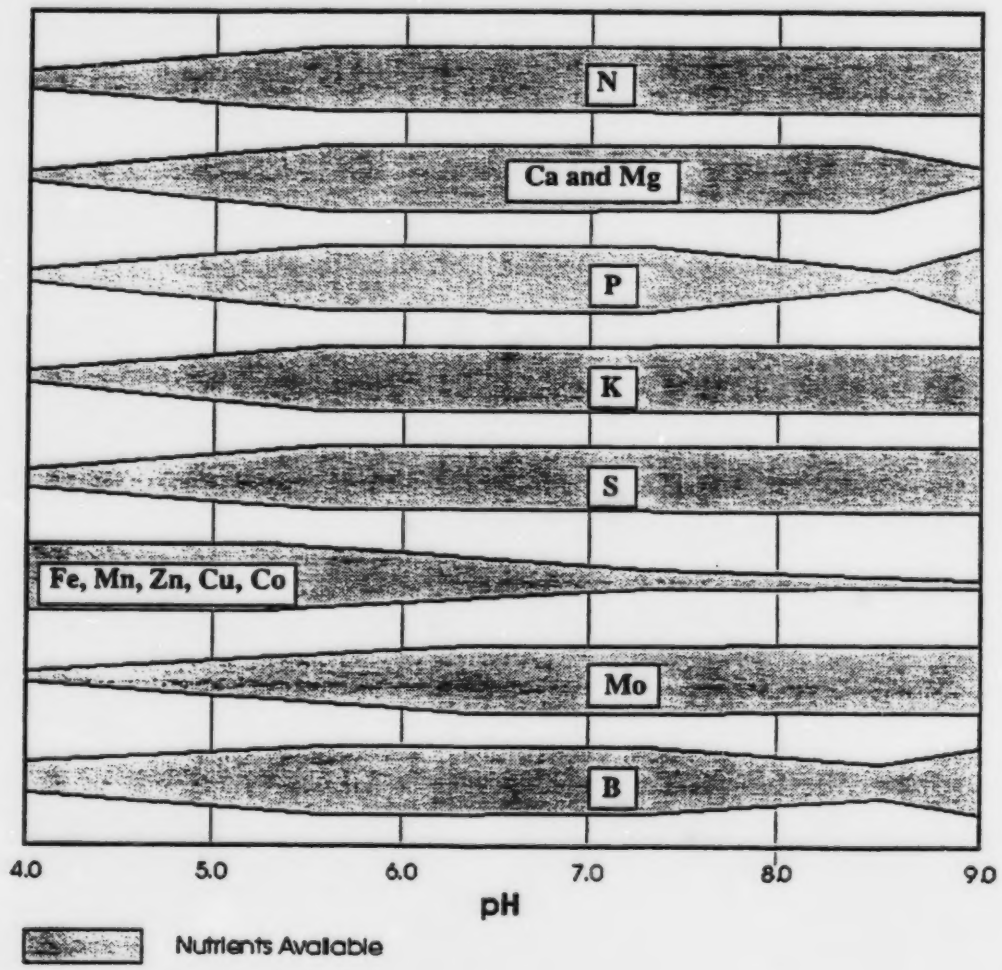


Figure 11: *Relationship between pH and the availablity of plant nutrients.*

Analysis:

Use Figure 8 to answer the following questions:

- What elements become less available to plants as the pH decreases?
- What elements become more available to plants as the pH decreases?
- At what pH are most nutrients available to plants?
- Plants have evolved to exist in different types of environments. One of the adaptations is to soil of different pH values.

Problem 3 - Do all plants require the same soil pH?

Observations:

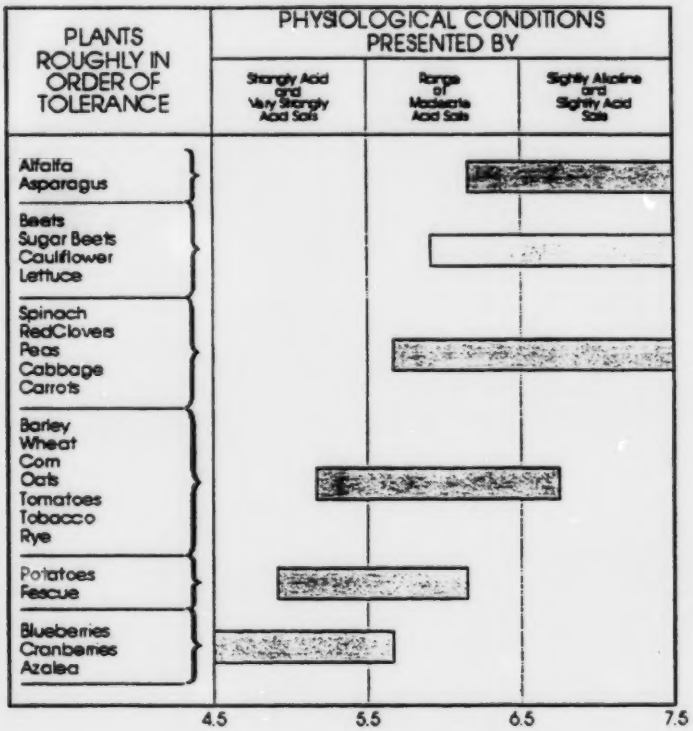


Figure 12: *Plant growth and pH values of soil.*

Analysis:

Use Figure 12 to answer the following questions:

- What soil pH is optimal for most plants?
- What generalization can you make about plant growth and pH?
- If the soil pH changes over a period of time what also will change?

Aluminium ions increase in concentration as the pH of soil becomes more acidic. Since $Al^{3+}_{(aq)}$ is toxic to many plants and animals, this observation and its consequences is significant. Figure 13 shows the relationship between different ions as soil pH changes.

Use Figure 13 on the next page to answer the following questions:

What happens to the concentration of $Al^{3+}_{(aq)}$ as the pH decreases?

What is the percentage of the following at a pH of 3?

a. $Al^{3+}_{(aq)}$

b. $Al(OH)^{2+}_{(aq)}$ and $Al(OH)_2{}^{+}_{(aq)}$

c. Exchangeable $H^{+}_{(aq)}$

d. Bound $H^{+}_{(aq)}$ and $Al^{3+}_{(aq)}$

e. Exchangeable base

What is the percentage of the following at a pH of 6?

a. $Al^{3+}_{(aq)}$

b. $Al(OH)^{2+}_{(aq)}$ and $Al(OH)_2{}^{+}_{(aq)}$

c. Exchangeable $H^{+}_{(aq)}$

d. Bound $H^{+}_{(aq)}$ and $Al^{3+}_{(aq)}$

e. Exchangeable base

$Al^{3+}_{(aq)}$ is toxic to many forms of life. Describe an experimental design that would allow you to determine the concentration of $Al^{3+}_{(aq)}$ that will affect the development of young fish.

COMPLEX ION CHARGES

Al has an oxidation number of 3^{+}. Hydroxide has an oxidation number of 1. A complex ion of one aluminum ion and one hydroxide ion will have a net charge of 2^{+}.

$Al(OH)^{2+}_{(aq)}$

A complete ion of one aluminium ion and two hydroxide ions will have a net charge of 1^{+}.

$Al(OH)_2{}^{+}_{(aq)}$

EXCHANGEABLE AND BOUND IONS

An ion is exchangeable if it is free to react with another ion. An ion is bound if it is not free to react with another ion.

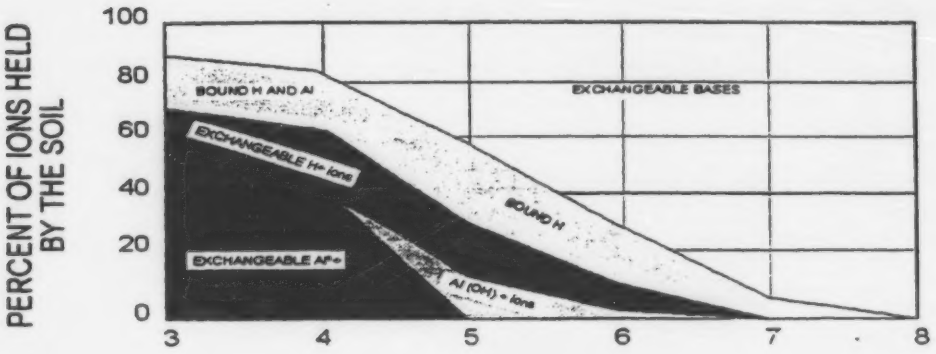


Figure 13: The relationship between soil pH and various other soil ions

Problem 4 - How does a change in pH affect a natural aquatic community?

Observations:

Information from other parts of Canada can help us understand the effects that acidic deposition could have on aquatic ecosystems in Alberta. The next four pages contain information about the living things found in a lake at different pHs.

pH above 6.0

Fish - flathead minnow, slimmy sculpin, lake whitefish, lake trout, white sucker, walleye, yellow perch, brook trout.

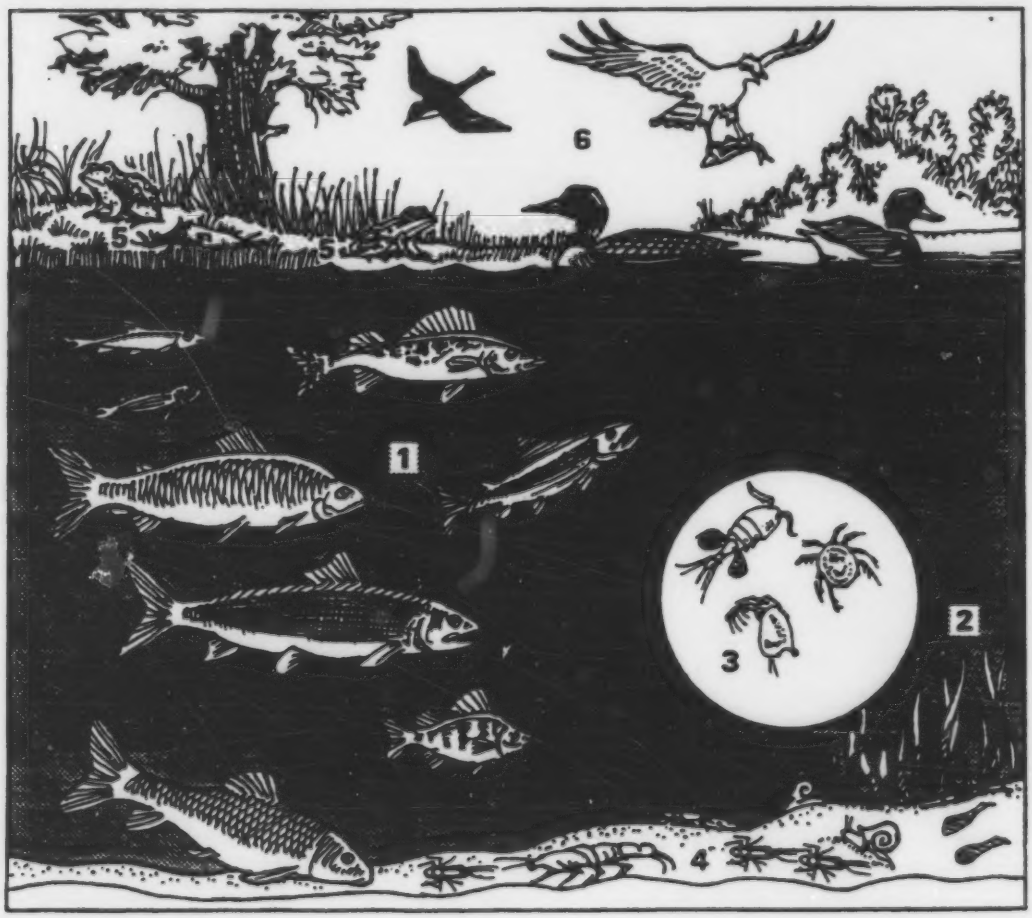
Algae - no algae mat growing on bottom of lake or on the edge of the lake. Picture showing vascular plant growth (species?).

Genera - zooplankton and phytoplankton (floating free in water), microscopic balloons of water fleas, and other genera such as copepods; could include some phytoplankton diversity (advice needed on species).

Zoobenthos - (bottom of lake)- crayfish, leeches, snails, mayflies.

Amphibians - frogs and toads of Alberta genera

Birds - loons, osprey, ring-necked duck, and tree swallow.



pH between 6.0 and 5.6

Fish - lake whitefish, lake trout, white sucker, walleye, yellow perch, brook trout.

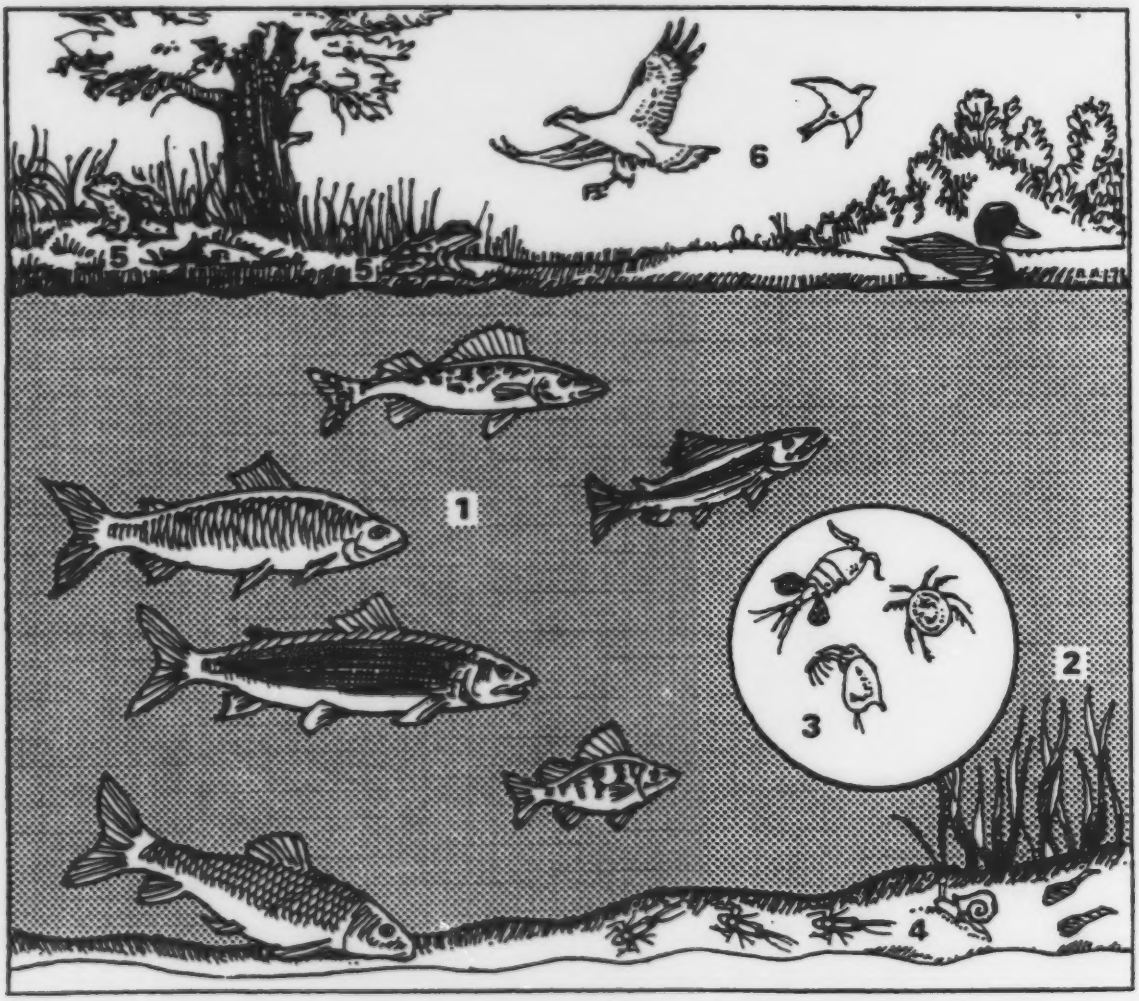
Algae - start of algae mat growing on bottom and on the edge of the lake; some growth of algae mat on vascular plants.

Genera - zooplankton and phytoplankton (floating free in water), microscopic balloons of copepods; slight change in phytoplankton diversity.

Zoobenthos - (bottom of lake), leeches, fewer snails and fewer mayflies.

Amphibians - frogs and toads of Alberta genera

Birds - Osprey, ring-necked duck and tree swallow.



pH between 5.5 and 5.1

Fish - yellow perch, brook trout

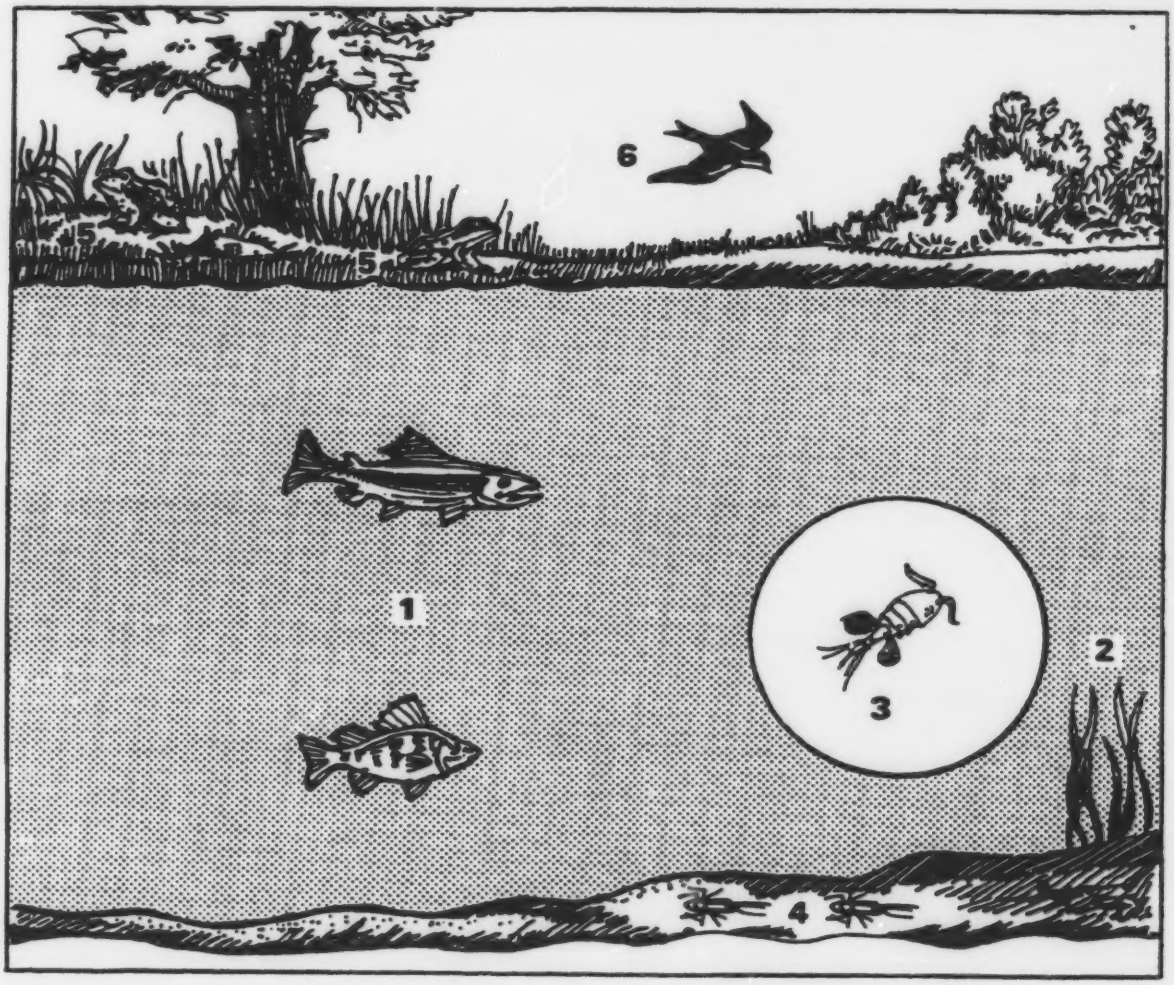
Algae - more algae mat growing on bottom of lake and on the edge of the lake. Also shows growth of algae on a decreased vascular plant population.

Genera - zooplankton and phytoplankton (floating free in water); decline in all genera. Increase in the dinoflagellate population.

Zoobenthos - (bottom of lake) - fewer mayflies

Amphibians - frogs and toads of Alberta genera

Birds - tree swallow



pH between 5.0 and 4.0

Fish - none

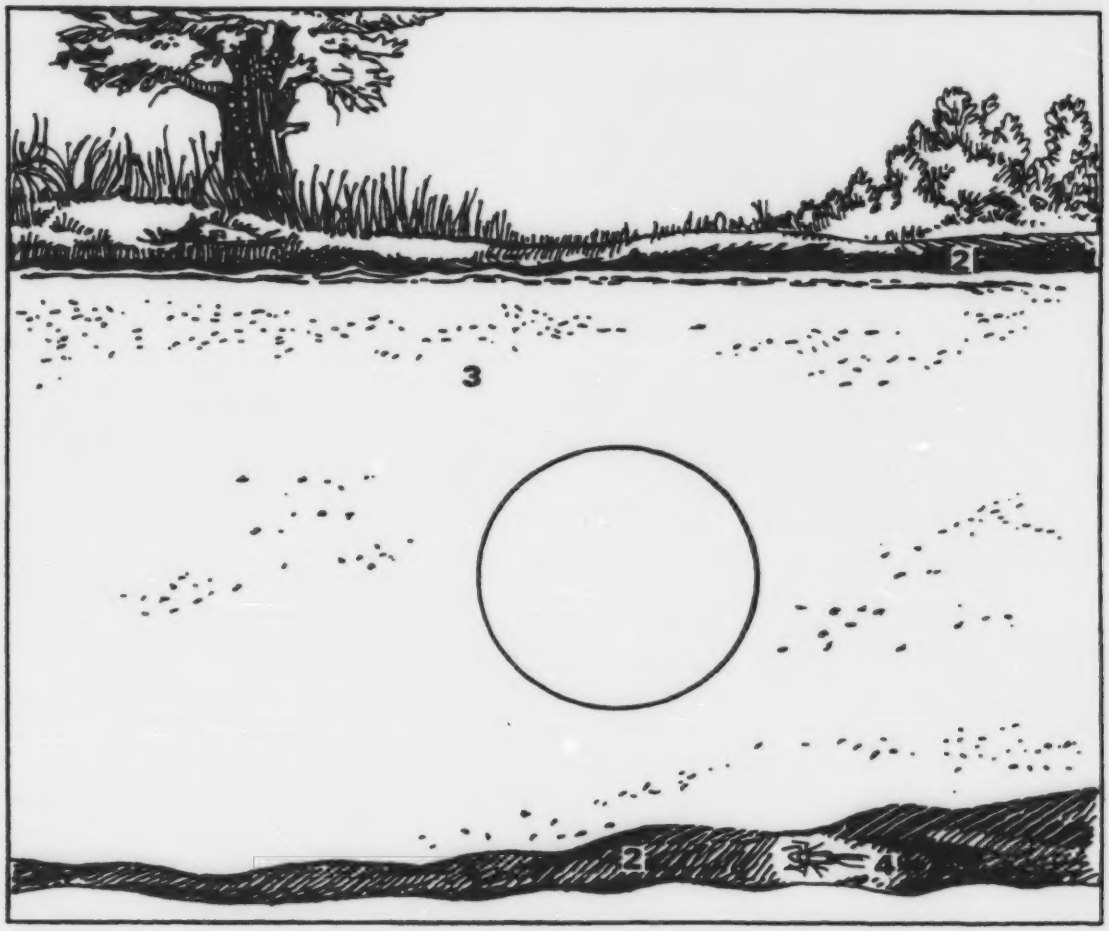
Algae - extensive algae growing on bottom of lake and on the edge of the lake; no vascular plants

Genera - zooplankton and phytoplankton (floating free in water); large dinoflagellate population; little diversity in genera

Zoobenthos - (bottom of lake)-very few mayflies

Amphibians - none

Birds - none



Analysis:

Use a chart similar to the one below to organize your observations of the preceding four pages.

Table 18: Comparison of existing species to various pH levels

pH range	Species present	Species lost	Other observations
Above 6.0			
6.0 - 5.6			
5.5 - 5.1			
5.0 - 4.0			

- What generalizations can you make about the acidification of lakes?
- What reasons may account for the decrease in bird populations?
- What factors may determine how fast lakes can become acidic?
- How would you determine the reason for the decrease in fish populations as the pH decreases?
- What species may be used to indicate if the pH of a lake is becoming more acidic?

CHAPTER FIVE

Solutions To Acidic Deposition

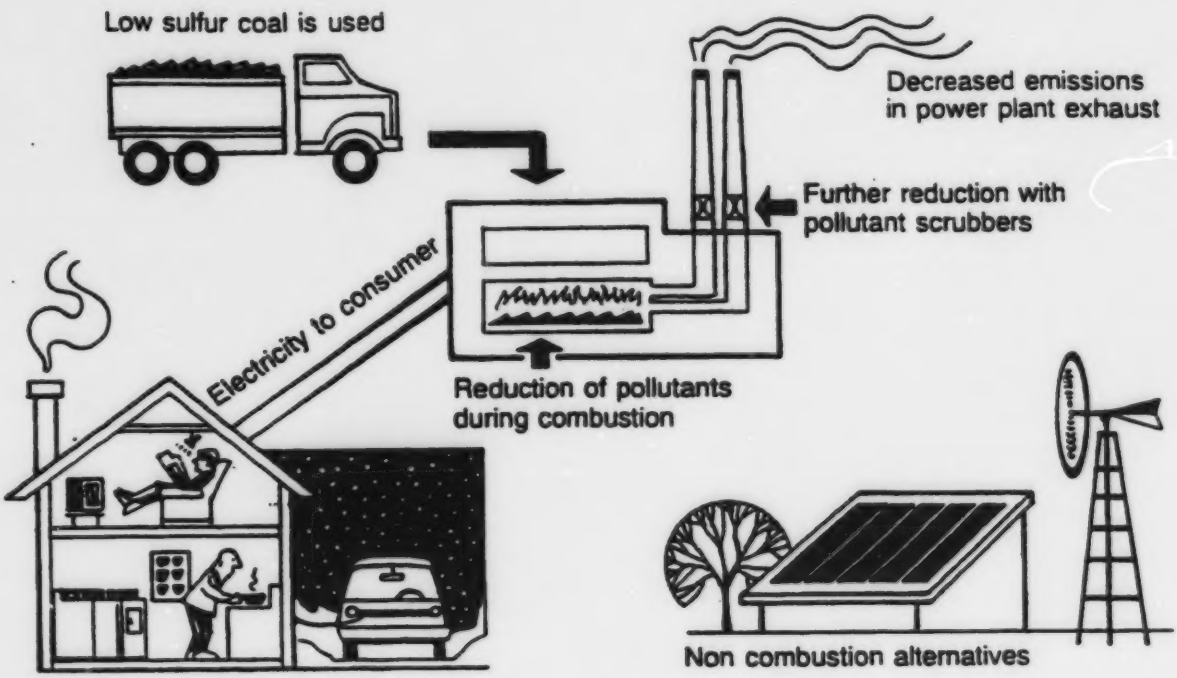


Figure 13: *Methods of decreasing sulphur dioxide and nitrogen oxide emissions*

As Figure 13 shows there are many ways to decrease the emissions contributing to acidic deposition:

- Decrease the amount of pollutant in the fuel before the fuel is used.
- Prevent the formation of pollutants during combustion of the fuel.
- Remove the pollutants from the exhaust and flue gases.
- Decrease the use of energy by conserving the energy produced.
- Change the methods of energy production to methods that employ non-combustion processes.

Decrease the pollutants in the fuel

Decreasing the number of pollutants in fuel before the fuel is used is possible in a number of cases. Most coal and oil fuels contain sulphur. Low sulphur oil only accounts for 20% of the known oil reserves. Low sulphur coal is abundant but is often not close to the industrial locations that use the coal. If we are to use coal and oil as a source of energy the problems of removing the sulphur will continue. The simplest technology to remove the sulphur from coal is to crush it and use water to remove the sulphur it contains. This technology would reduce the emissions of sulphur dioxide by 20% - 40%. Removal of the sulphur from heavy oil can be done during the refining process and will reduce the production of sulphur dioxide by 15%.

Many factors enter into deciding on one fuel over another. Some of the factors that need to be considered are availability, transportation costs, amount of sulphur in the fuel, and the type of utility that will use the fuel.

Another factor that should be considered is that not all fuels release the same amount of energy. The combustion of one mole of coal releases –393.5 kj/mol of energy. The combustion of one mole of natural gas releases -993 kj/mol.

$$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)} \quad Hf = .393.5kj$$

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)} \quad Hf = .993kj$$

From this we can see that the burning of natural gas produces more than twice the amount of energy as the burning of coal. This would result in less than half of the amount of carbon dioxide entering the atmosphere. The effect on acidic deposition would depend on the amount of sulphur that was contained in the original fuel.

Decrease pollutants during combustion

A number of technologies in multistage burners or LIMB uses powdered coal and limestone mixed together for combustion. The limestone combines with the sulphur in the coal to produce gypsum. Since the coal is powdered the combustion process can be carried out at a much lower temperature. The lower temperature decreases the amount of nitrogen oxide compounds by 50%. The removal of the sulphur as gypsum decreases the amount of sulphur dioxide by 80%.

How gypsum is produced in lime injection multistage burners:

$$CaCO_{2(s)} + Heat \longrightarrow CaCO_{(s)} + CO_{2(s)}$$

$$2CaO_{(s)} + 2SO_{2(g)} + O_{2(g)} \longrightarrow 2CaSO_{4(s)}$$

The higher the temperature the greater the amount of nitrogen oxide produced. By lowering the temperature for combustion the amount of nitrogen oxide compounds produced is lowered.

$$N_{2(g)} + O_{2(g)} + \text{Heat} \longrightarrow 2NO$$

$$2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)}$$

Other technologies make use of the same ideas of LIMB. In another technology the fuel is burned in a perforated bed containing limestone. Air is blown into the combustion chamber, causing the coal and limestone to float while combustion occurs. The limestone removes the sulphur dioxide and the lower combustion temperature decreases the amount of nitrogen oxide compounds produced.

Remove pollutants from the exhaust and flue gases

A common method of reducing the amount of sulphur dioxide is to remove it from the exhaust and flue gases.

Scrubbers remove the sulphur dioxide by either a wet or dry technology. Wet scrubbers use water and limestone to wash the exhaust gas before they are sent up the stack. Wet scrubbing produces calcium sulphite and calcium sulphate.

$$CaCO_{3(s)} + \text{Heat} \longrightarrow CaO_{(s)} + CO_{2(s)}$$

$$2CaO_{(s)} + 2SO_{2(g)} + O_{2(g)} \longrightarrow 2CaSO_{4(s)}$$

or

$$CaO_{(s)} + SO_{2(g)} + \longrightarrow CaCO_{3(s)}$$

Dry scrubbers use ammonia sprayed into the flue gases. The ammonia combines with the sulphur dioxide to produce ammonium sulphate that can be used as a fertilizer.

$$NH_{3(aq)} + SO_{2(g)} \longrightarrow (NH_4)_2SO_{4(s)}$$

Other, more advanced technologies are under development. Electron beam methods are used to produce fertilizers from the flue gas; catalysts are being used to change the nitrogen oxide compounds into harmless nitrogen gas. Burners are being developed to reduce the temperature of combustion and as a result reduce the emission of nitrogen oxide compounds.

Coal burning technologies being developed to produce electricity are a good example of how technology can be used to solve some of the problems associated with the use of a particular fuel.

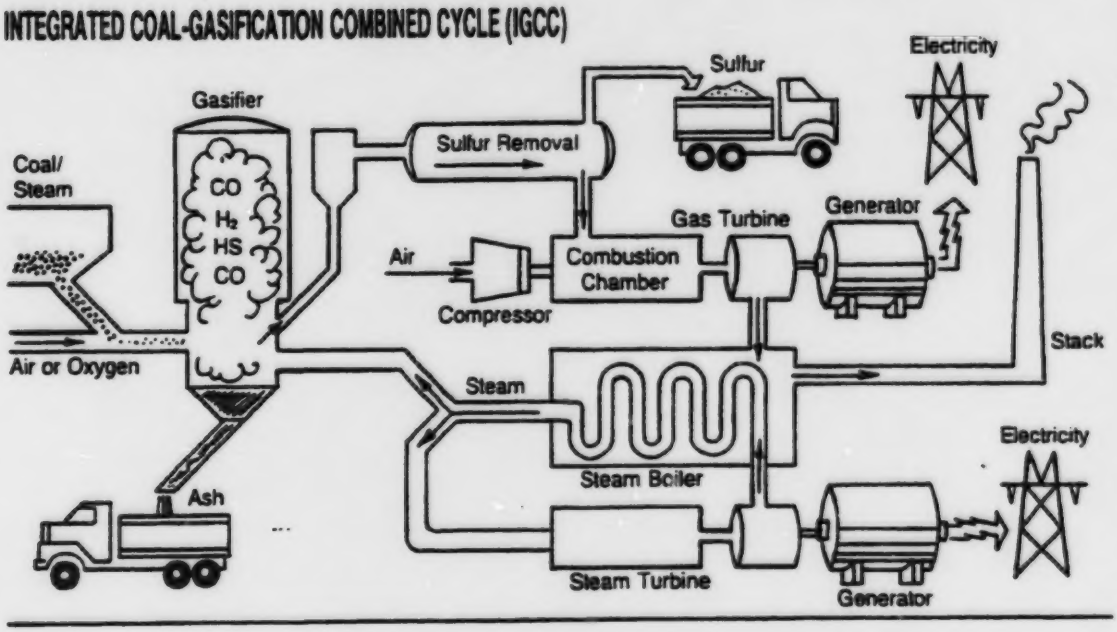


Figure 14: *One advanced technology to use coal to produce electricity.*

Figure 14 shows an advanced coal burning technology where the coal is converted to a gaseous mixture by reaction with oxygen and water. The hot gases are used to power a gas turbine; the heat from the combustion of the gases is used to produce steam that powers a steam turbine. The sulphur is removed from the gas and from the exhaust entering the stack. This technology is more efficient than conventional systems at converting the energy contained within the coal into electricity. The efficiency of the conversion of raw energy contained in fuel into useful energy is also one of the factors that will affect the amount of acidic deposition from a utility.

Efficiency of a system is defined as the form of energy that you wanted divided by the total energy that was available. For example, the efficiency of a car would be the useful energy of motion divided by the total energy that was available from the burning of the fuel. This number is about 0.40 for both a car and for the reactions that occur inside of you.

There are over 500 million automobiles in the world today. In industrialized countries the automobile accounts for as much as one-half of the nitrogen oxide compounds produced. Any combustion process will result in the production of carbon dioxide and nitrogen oxide compounds. The catalytic converters on cars reduce the production of nitrogen oxide compounds by 33 - 50%. The catalytic converter uses platinum and rhodium to lower the amount of energy necessary to change nitrogen monoxide into nitrogen gas.

The use of the catalytic converter is one way that we can directly decrease the amount of acidic deposition.

$$2CO_{(g)} + 2NO_{(g)} \xrightarrow{Pt_{(s)} + Rh_{(s)}} 2CO_{2(g)} + N_{2(g)}$$

Analysis:

Construct a table in your notebook similar to the one below. Use the ideas presented on solutions to acidic deposition to fill in the information.

Table 19: Comparing methods for reducing acidic emissions

Method	Decrease in $SO_{2(g)}$ emitted	Decrease in $NO_{x(g)}$ emitted	Process	Notes on process
Decrease in pollutant in the fuel			1. Washing coal 2. Refining oil	
Decrease pollutant during combustion			1. LIMB 2. Other	
Remove pollutant from the exhaust gas			1. Scrubbers 2.Catalytic converter	

- What factors may prevent industry from removing all sulphur from fuels?
- Do all fuels produce the same amount of energy?
- What are some economic advantages to removing sulphur before it enters the atmosphere?
- What reaction occurs inside the catalytic converters in cars?
- Why is the use of catalytic converters important?

Many parts of the world, including Canada, must contend with a problem that already exists. The adding of lime, limestone, or dolomite to acid lakes can re-establish a normal pH.

Lime $CaO_{(s)}$

Limestone $CaCO_{3(s)}$

Dolomite $CaCO_3MgCO_{3(s)}$

Lime reacts with water to produce calcium hydroxide:

$$CaO_{(s)} + H_2O_{(l)} \longrightarrow Ca(OH)_{2(aq)}$$

The calcium reacts with the acids in the lake:

$$2H_2CO_{3(aq)} + Ca(OH)_{2(aq)} \longrightarrow Ca(HCO_3)_{2(aq)} + 2H_2O_{(l)}$$

In a similar way, both limestone and dolomite decrease the concentration of acid.

The addition of a base to return a lake to normal pH is only one way of dealing with acidification of lakes after the fact. Only a decrease in the production of compounds that lead to acidic deposition will be able to prevent the acidification of lakes. One of the major problems with adding a base to a lake is that the winter snow melt adds so much acid to the lakes that the surge in acidity damages the life of the lake even though the pH of the lake is normal for most of the year.

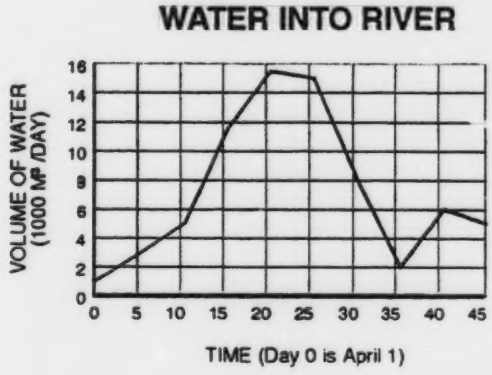


Figure 15: The volume of water entering a river as snow melts

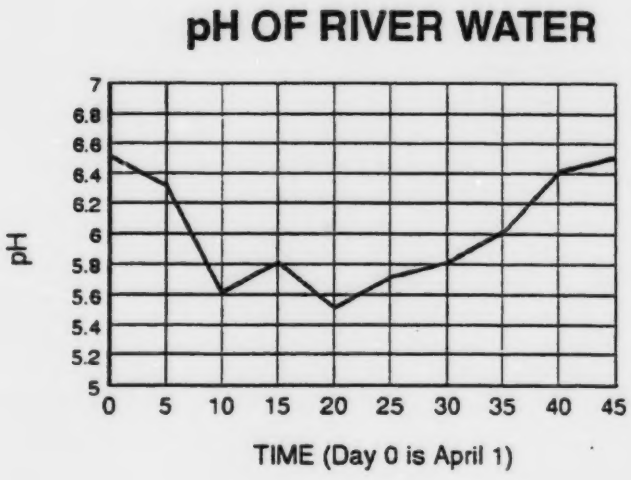


Figure 16: The pH of the river water as snow melts

Analysis:

- How can the pH of a lake be increased?
- Is the neutralizing of acid an effective solution to acidic deposition?
- Use Figure 15 and Figure 16 to describe how snow melt affects the pH of lakes.
- How will an acid surge affect the life in lakes?
- How does acid surge affect the effectiveness of treating acid lakes with lime?

Activity 10 - Evaluation of Competing Technology

Observations: You will use Table 20 as the source of your observations. From this rather complex set of observations you will perform an analysis of the information presented.

Table 20: A comparison of six technologies to produce electricity from coal and gas

	Plant Cost ($/kilowatt produced)		Reduction n sulphur dioxide reduced (%)		Nitrogen Oxide compounds (mg/million joules of electricity)		Carbon dioxide emitted (kg of carbon as carbon dioxide/kilowatt/hr)		Efficiency (% of stored energy to electricity)	
	COAL	GAS	COAL	GAS	COAL	GAS	COAL	GAS	COAL	GAS
Technology A	1600	760	90	100	300	180	0.25	0.14	34	36
Technology B	1700	520	99	100	25	15	0.2	0.1	42	47
Technology C	1200		90		60		0.19		42	
Technology D	1300	410	99	100	25	15	0.24	0.12	40	40
Technology E	1030	400	99	100	21	10	0.2	0.1	42	47
Technology F	1250	700	99	100	23	12	0.18	0.095	48	52
Average	**1346**	**558**	**96**	**100**	**75.5**	**46.4**	**0.21**	**0.11**	**41**	**44**

Analysis:

The five figures below are of the average values of each of the technologies. They will allow you to evaluate the use of coal and natural gas as a source of fuel to produce electricity.

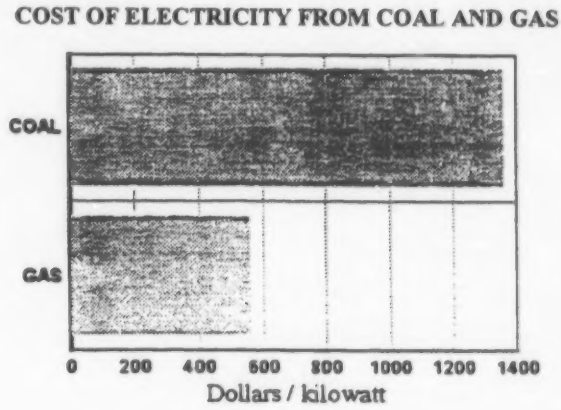


Figure 17: Plant cost in dollars/kilowatt of capacity

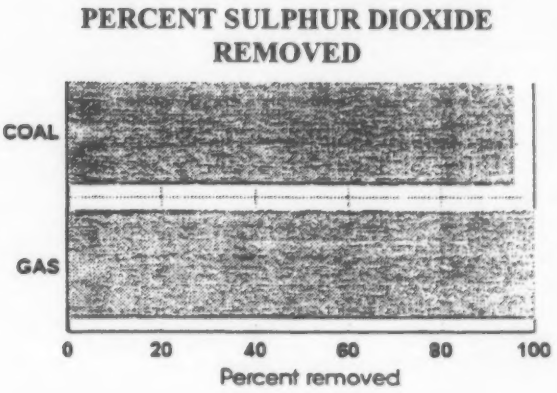


Figure 18: Percent reduction in $SO_{2(aq)}$ emitted

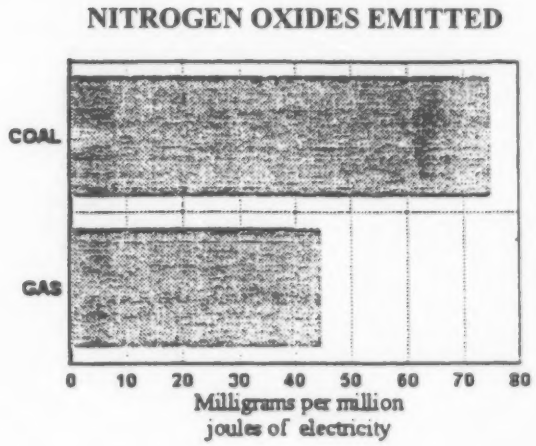
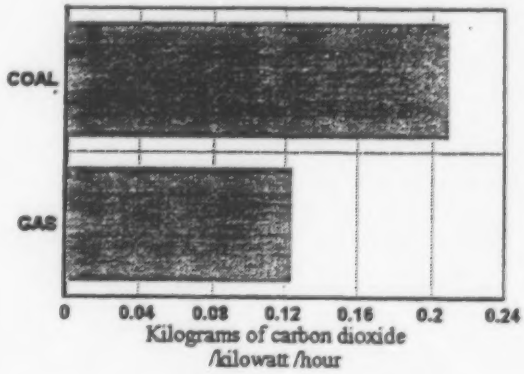


Figure 19: Nitrogen oxide compounds emitted in milligram joules of electricity produced.

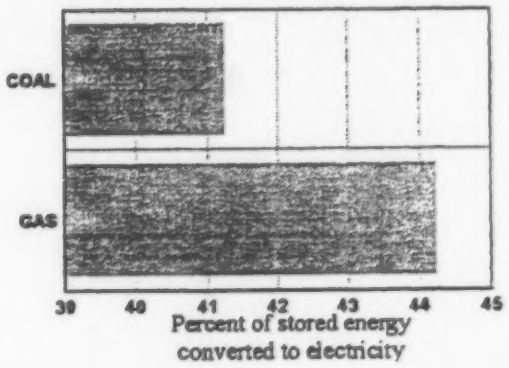
CARBON DIOXIDE EMITTED

Figure 20: Carbon dioxide emitted in kilograms of carbon as carbon dioxide kilowatt hour



EFFICIENCY

Figure 21: Efficiency in percent of stored energy converted to electricity



- Using Figure 17 to Figure 21, what conclusion can you make about the use of coal and gas as a source of energy to produce electricity?
- What factors may determine the fuel that is used?
- What are the advantages of using gas to produce electricity?
- What other information would you need before deciding on the use of gas or coal as an energy source?

Deciding Which Technology to Use

The following figures compare the five technologies presented in Table 20.

Figure 22: Plant cost in dollars/kilowatt of capacity

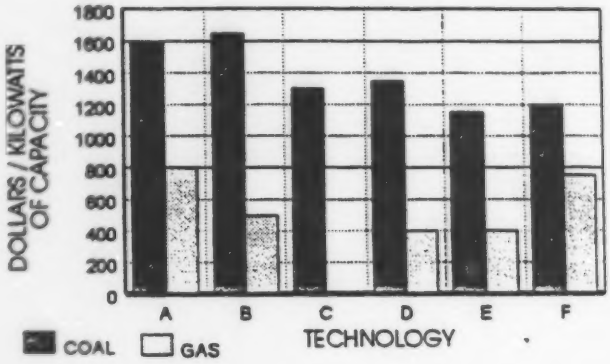


Figure 23: Percent reduction in $SO_{2(g)}$ emitted

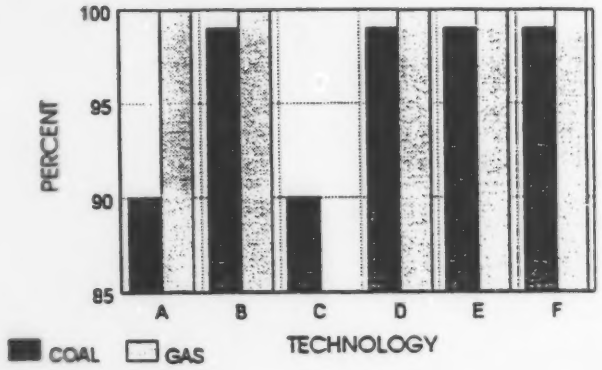


Figure 24: Nitrogen oxide compounds emitted in milligrams per million joules of electricity produced

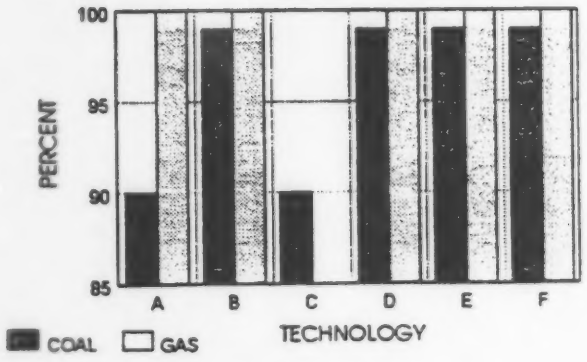


Figure 25: Carbon dioxide emitted in kg of carbon as CO_2/kilowatt/hour

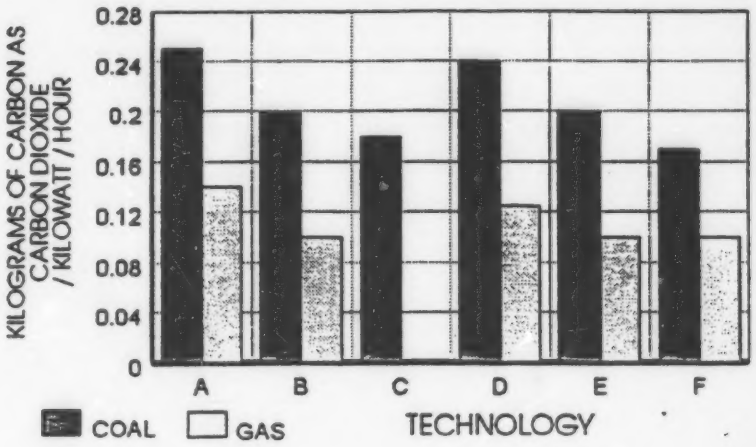
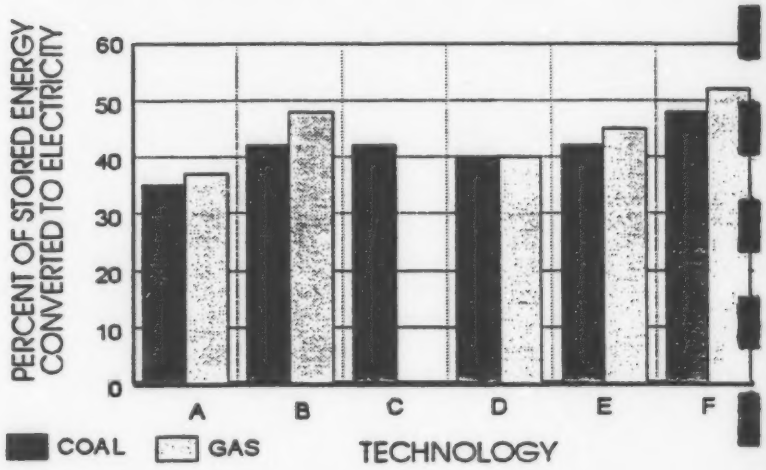


Figure 26: Efficiency in percent of stored energy converted to electricity



Use the data provided in the graphs from Figure 22 to Figure 26 to decide on the "best" technology.

- What technology did you select?
- What reasons did you have for making your selection?
- If coal is the only source of energy, what technology would you select?
- What other factors may affect your decision of the type of technology to use?

Conservation of energy

Another use of technology is to decrease the amount of energy that is used. This would have a direct effect on the amount of carbon dioxide, sulphur dioxide and nitrogen oxide compounds, by decreasing the amount of fuel needed. There are two ways to do this:

- Use present technology to increase the efficiency of energy use.
- Develop new technologies that are more efficient.

Industry, public buildings, and personal homes can utilize existing technology to increase the efficient use of energy. Some of the personal actions that we can take to increase energy efficiency in our homes are:

- Improve weather stripping around windows and doors.
- Purchase energy efficient appliances.
- Increase the insulation used in homes.
- Use a timer when plugging in block heaters on cars.
- Use public transit.
- Insulate the water heaters in homes.
- Purchase cars that use less fuel.

The development of new technology will decrease the amount of energy that we use. Occupancy sensors will determine if someone is in the room and put out the lights if the room is unoccupied. Dimming devices will measure the amount of light from windows and adjust the amount of additional light needed. Reflectors in fluorescent light fixtures will be designed to reflect more of the light into the room, allowing half the number of bulbs to provide the same illumination. Compact fluorescent lights will replace the existing incandescent bulbs providing the same illumination while consuming one-fourth the power. Public transportation will become much more common and efficient, reducing the use of private transportation.

Non-combustion energy sources

Alternatives to the consumption of fossil fuels are inevitable. The quantity of fossil fuels on our planet is limited. Other sources of energy will need to be developed.

Nuclear energy accounts for up to 70% of the energy produced in some countries of the world. Despite a different range of problems associated with the use of nuclear energy, the use of nuclear energy will increase. The energy produced by nuclear reactions is far larger than the amount of energy released from combustion reactions. For example:

The amount of energy released from one mole or 16 grams of natural gas is 993 kj of energy.

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)} \quad Hr = .993kj$$

The 993 kj of energy is enough energy to raise 23.7 L of water 10°C. One of the reactions occurring inside of nuclear reactors can be represented as follows:

$$^{235}_{92}U + ^{1}_{0}n \text{ ---------- } ^{142}_{56}Ba + ^{92}_{36}Kr + 2\ ^{1}_{0}n \quad H = 1.72 \times 10^{10}\ kJ$$

The amount of energy released from 16 grams of the uranium is 1.2×10^9 kj of energy. This amount of energy is enough to raise the temperature of 20 million L of water by 10°C.

The number 235 is the atomic mass or the total number of protons and neutrons in the nucleus of this isotope of uranium. The number 92 is the number of protons in the uranium atom. Notice that the reaction uses one neutron to produce two neutrons as a product. This is what produces the chain reaction in reactors.

Notice that the total number of protons in the reactants is equal to the total number of protons in the products. Also notice that the total atomic mass of the reactants is equal to the total atomic mass of the products. In actual fact the mass reactants and products isn't the same and the loss of the mass in the equation is changed into energy as represented by the famous equation $E = mc^2$.

The most important form of energy for the earth is the sun. Through the process of photosynthesis the energy liberated from the nuclear reactions of the sun is trapped in the form of living tissue. Even the fossil fuels that we burn were once living things that obtained their energy from the sun. The nuclear reactions in the sun are of a different form than occur in the nuclear reactors of today. The nuclear reactions in the sun are called fusion reactions. In a fusion reaction light nuclei (containing both the protons and neutrons) are combined or fused to form an element with a large nuclei. The overall equation results in a loss of mass that is changed into energy. The uranium reactions that occur in nuclear reactors are fission reactions. In fission reactions elements with a large nuclei are changed into elements that have smaller nuclei. One of the fusion reactions in the sun can be summarized as:

$$2\ ^{1}_{1}H + ^{1}_{0}n \text{ ---------- } ^{4}_{2}He \quad H = 2.7 \times 10^{9}\ kJ$$

Fusion reactions do not produce the same long-lived radioactive compounds as fission reactions. For this reason the research into controllable fusion reactions may be important in the future production of energy.

Energy from the sun also powers the production of energy from water. Sunlight evaporates water; the rain falls into rivers and lakes and turns generators that produce electricity.

Wind is the result of the sun heating the atmosphere. Wind farms are being developed to use wind energy to generate electricity.

Solar collectors are being developed to collect energy from the sun to heat a liquid. The heat is used to power a turbine that produces electricity. Solar collectors, like the one in solar calculators, are being developed that change the energy of the sunlight directly into electricity.

One of the problems with the use of solar energy is the intermittent production of the energy. Excess electrical energy from hydroplants and solarplants could be stored by producing hydrogen and oxygen by electrolysis.

$$\text{electrical energy} + 2H_2O_{(l)} \longrightarrow H_{2(g)} + O_{2(g)}$$

The hydrogen produced would make an excellent fuel, in that its combustion would produce no sulphur dioxide, carbon dioxide or nitrogen oxide compounds.

$$H_{2(g)} + O_{2(g)} \longrightarrow \text{energy} + 2H_2O_{(l)}$$

Many of the non-combustion solutions to acidic deposition have their own environmental problems. The burning of fossil fuels is a non-renewable resource. There is a limit to the amount of time that energy can be produced in this way. With continued research and the necessary vision, we will move from using non-renewable energy to renewable energy sources.

- List at least four methods that industry can use to conserve energy.
- List at least four methods that could be used to conserve energy in public buildings.
- What problems are associated wit the use of nuclear energy?
- What is the difference between a fusion and fission reaction?
- Are all forms of renewable energy dependent on the sun?
- Is nuclear energy a renewable form of energy? Explain your answer.

CHAPTER SIX

Acidic Deposition - A Socio-Economic Perspective

Notes to the Teacher

Acidic deposition is a topic that provides an opportunity for teachers and students to look at a very serious environmental concern that has local and global implications. This issue has economic, ecological, political and social perspectives. In previous chapters, the emphasis was on the science of acidic deposition. This chapter is dedicated to the analysis of acidic deposition from a socio-economic perspective. The future state of our environment depends on the policies and strategies decided upon today. Included in this unit are activities that will:

- provide insight into the importance of citizen involvement in regional and global issues
- encourage the development of communication skills, critical thinking, and analysis of alternate perspectives
- provide the opportunity to investigate and research relevant information
- promote tolerance and understanding of different points of view
- encourage personal action
- promote the idea that citizens have a role in the policies and decisions that are being made
- provide a means to understand the process and difficulties involved in decision making
- demonstrate that economics, development strategies, government decision making and public participation are all key elements in determining the present and future state of our environment

The intent of this chapter is to facilitate the examination of the dynamics involved in the process of issue resolution and decision-making.

Inside Acid Rain...A Socio-Economic Perspective

There is a great deal of scientific uncertainty surrounding the acidic deposition issue. Yet, even if these uncertainties were resolved tomorrow, the decisions on how to control acid rain would not be easily made.

The real story of acid rain looks beyond the environmental uncertainties and begins in the world of politics, economics and social attitudes. The combined influences from these three arenas will determine the course of action to be taken on the acid rain issue.

This unit will take a closer look at some of the questions at the heart of the acid rain debate. We will examine the underlying causes that have prolonged this issue and investigate the factors responsible. We will look at the series of events that set in motion the entire acid rain controversy and ask questions such as:

- Why has this issue continued to remain unresolved for so long?
- What are the factors responsible?
- What is the government's role in resolving or contributing to this issue?
- What role does the public have in resolving or continuing this issue?
- What is the relationship between Canada and the United States Government with regard to this issue?
- What are the economic consequences of controlling acid rain?
- What are the economic and environmental costs of not controlling acid rain?
- Can economic and environmental considerations be reconciled?
- Can the acid rain issue be resolved using sustainable development strategies?

The goal of this chapter is to provide you with a brief overview of the acidic deposition issue as viewed from the social, economic, and political perspectives. Through this, we will see how much influence each of these factors can have on the decision-making policies that are required to resolve environmental or other issues of national and international concern. The acid rain debate is really a reflection of the political atmosphere and attitudes of our time.

Acid Rain: The Canadian Perspective

As Canadians, we are very concerned about acid rain. This issue goes straight to the forefront of the Canadian environmental scene. According to public opinion polls taken over the last fifteen years, Canadians show a much higher degree of sensitivity, awareness and concern regarding this issue than their American neighbours. To decrease the emissions responsible for causing acidic deposition, many Canadians have expressed a willingness to pay more for their utilities and purchases. There has been an indication also, the most Canadians would accept the employment and economic consequences that could result from increased pollution control measures.

In contrast, until recently, the U.S. government, large American corporations and even the American population did not seriously recognize the significance of acid rain. This difference in perspectives resulted in a fifteen-year political skirmish that threatened to jeopardize U.S./Canada relations. Even matters completely unlinked to the acidic deposition problem were affected. Over the years, Canada has tried to influence the American government to legislate stronger emission control measures. These attempts have sometimes been futile and the results disappointing. Yet these efforts, combined with other events occurring in the United States, have recently led to some promising actions implemented by the American government.

In Canada, the acidic deposition problem has reached and surpassed its fifteenth anniversary. Knowing the history is helpful because it provides a greater insight into the complexities associated with reaching a resolution. As we will see later, these events did not occur out of any intentional animosity between the Canadian and American governments, but resulted from various political and economic pressures within their own boundaries. In many respects, it is these underlying political factors that make up the real acid rain story. These issues will be discussed in greater detail when we examine the Canadian-U.S. relationship.

Acid rain: A Brief Canadian Case History

Chronology of events:

1950's	Acidified lakes near Sudbury, Ontario were identified.
1976	CANSAP (Canadian Network for Sampling Precipitation) stations were established to monitor acidic precipitation in various locations throughout Canada.
1978 (July)	Canada and U.S. establish a Bilateral Research Consultation Group (BRCG) that is responsible for facilitating the exchange of information between the two nations as well as to coordinate research in order to create a scientific data base that could be used to develop pollution control policies.
1979 (July)	Great Lakes Advisory boards warned of damage to aquatic and terrestrial ecosystems in the Great Lakes Basin by acid rain.
1979 (July)	Canada and U.S. announce their intention to develop a co-operative agreement on transboundary air quality.
1979 (July)	BRCG released its first report which essentially recognizes acidic precipitation as a common international concern. There is also recognition of decreasing numbers of various fish species in some lakes in Ontario and the Atlantic Provinces. Other areas of potential concern include a reduction in productivity within the forestry and agriculture sectors.
1980 (August)	A Memorandum of Intent (MOI) was signed between the United States and Canada. This is the first step on the process towards a bilateral agreement between the two nations. Five work groups were established to come up with the scientific and technical background required to make up a bilateral agreement.
1981-83	The initiatives proposed under the MOI begin to deteriorate and eventually break down completely. Canada and the United States release separate and independent reports from one of the established work groups. Other work groups do not even submit final reports. Essentially, the U.S. rejects the Canadian proposals for emission reductions as being premature and recommends further studies as opposed to implementing controls. Canada had proposed that both countries reduce their emission levels by approximately half of 1980 levels to 20kg per hectare (18 ponds per acre) per year by 1986.
1983 (Feb.)	The independent reports released by the work groups are reviewed by separate peer review panels. The Canadian version is reviewed by the Royal Society of Canada; the American report is reviewed by the U.S. Office of Science and Technology Policy. There is some question as to how impartial a U.S. administrative review panel can be.

1983 (May)	The Royal Society of Canada releases its review of the work group report which essentially agrees with the suggested recommendations. They conclude that prompt action to reduce emissions is required by the United States and Canada.
1983 (June)	Groups in the Untied States, including the Office of Science and Technology Policy, release reports to support the main points raised by the Canadian Government. These reports suggest a link between industrial emissions and acidic deposition.
1983 (Aug.)	Canada and the U.S. sign an agreement to study the long-range transport of air pollutants caused by winds along eastern North America. This is in response to the continued denial by the Midwestern U.S. that they are responsible for the acidic emission volumes that are being deposited in the U.S. northeast states and Canada.
1983 (Oct.)	During the third meeting of Canada's External Affairs Minister and the U.S. Secretary of State, Canada's Environment Minister, who is also in attendance, expresses Canada's disappointment and impatience over the U.S. lack of effort and commitment to control acid rain.
1984 (July)	The U.S. Office of Science and Technology Policy completes its review of the report submitted by the work group established by the MOI. Included in their review is a support for the development of sulphur dioxide controls.
1985	The Canadian Federal Government and the seven provinces east of Saskatchewan agree to an acid rain abatement program that will reduce sulphur dioxide emissions by 50 percent of 1980 levels by 1994.
1985 (July)	Canada signs an international agreement along with twenty other nations at a United Nations Economic Commissions for Europe conference on long-range transportation of airborne pollutants. The agreement is to reduce sulphur dioxide transboundry movement by 30 percent of 1980 levels by 1993. The United States and the United Kingdom do not sign this agreement.
1985	A U.S. district court rules that the Environment Protection Agency (EPA) must recognize and implement the U.S. Clean Air Act clause that deals with international air pollutants. The order is for seven states, mostly in the Midwest, to reduce emissions. This ruling is appealed. The Clean Air Act provision states that the U.S. must take measures to reduce airborne pollutants that cross international boundaries if the country receiving these pollutants also has within their own legislation, a means to control emissions going to the United States. This is known as a reciprocity agreement.
1987 (June)	Acid rain legislation tabled in the U.S. Senate.
1987 (June)	Acid rain bill tabled in the U.S. House of Representatives.
1990 (Nov.15)	U.S. Clean Air Act revisions signed into law.
1991 (Mar.13)	A bilateral air quality accord is signed between the U.S. and Canada

Canada-United States Relations

When asked to describe themselves, Canadians often start by pointing out how different they are from their American neighbours. Despite these differences, there are many similarities that are shared between these two nations. From this, a political relationship has evolved which has linked the two countries in many economic, political and cultural directions. Both governments pride themselves on their "friendly" relationship with each other and have developed a variety of diplomatic channels in order to foster this.

There are situations, however, where events and internal interests have placed a strain on this "friendly neighbour" foreign policy. Political situations in local regions often have greater influence on policy decisions than pressures from more distant political neighbours. This influence applies to trade, economics, employment and even environmental issues. Even so, while attempting to provide for the needs of their citizens, both countries have made efforts to resolve any disputes through legal or diplomatic avenues.

The acidic deposition issue, however, has proven to be immune to these more familiar means of conflict resolution and has become a diplomatic thorn in the side of both countries. The acid rain issue has become a true testing ground for the commitment to the "friendly neighbour" policy that each government claims to support.

As the acid rain debate progressed, Canadians presented themselves as being the "innocent victims of these treacherous emissions" pouring northward from the coal-fired generators and industries of the Midwestern states. Although this idea of "Canadian innocence" has been hotly debated, there is no doubt that even with aggressive pollution control measures instituted in Canada, emissions in the United States would also have to be significantly reduced. Recognizing this, the Canadian government began putting pressure on the United States to initiate pollution control measures that would match their own.

Specifically, the Canadian government asked the United States to show initiatives on the following two items:

To reduce sulphur dioxide emissions so that total deposition of wet sulphate falling on Canadian soils would be no more than 20 kg per hectare. (This would mean a reduction of U.S. emissions by about fifty percent of 1980 levels.)

To sign a bilateral agreement that would include a joint pollution control effort involving cooperative research and monitoring as well as the development of a legal mechanism to help resolve transboundary air quality disputes.

Before moving towards a resolution with the Canadian government, the United States decided to take a "wait and see" position. Other (more vocal) critics of this policy labelled it as the "analysis first" position because of the tendency of the U.S. government to spend money on further research rather than risk the economic and political consequences of implementing pollution control measures.

There were several factors that influenced the policy-making decisions of each government. They include:

Awareness

Canadian citizens were extremely sensitized to the acid rain problem and were alarmed enough to want to take appropriate action. This was a result of an extremely successful marketing campaign by the Canadian government and motivated interest groups. The intent of this marketing strategy was to inform Canadians about what acid rain was, what it did, who was responsible and what could be done to reduce the threat. During the early 1980's almost 80 percent of the Canadian population was aware of the acid rain problem compared to only 15 percent of the American population.

Awareness of events occurring outside national boundaries

Canadians tend to be very familiar with events that occur in the United States. The American population however, does not hold the same level of awareness concerning events occurring in Canada. This difference could be attributed to two factors; population distribution in Canada has almost 80 percent of the population living close to the U.S. border. Canadians have ample opportunity to become aware of occurring within the United States. This same familiarity, however, does not hold true with Americans. Many U.S. citizens are virtually unaware of the issues and events that play on the Canadian side of the border. Any political pressure by the American public to reduce emissions going into Canada was virtually non-existent during the early 1980's. The government was much more easily influenced by the powerful lobby groups opposing emission controls because there was little resistance from environmentally concerned U.S. citizens.

Influence of lobby groups

Canadians remained frustrated by their own government's attempts to resolve this political stalemate. Recognizing that more must be done, a powerful and influential lobby group emerged in Canada. This group, called the Coalition Against Acid Rain, began a series of aggressive actions to influence a more rapid resolution of this conflict. These approaches included:

- Continued lobbying on the political front.
- Implementing a high impact marketing approach to educate American people about the effects of acid rain.
- Using the courts to bring the issue before the justice system.
- Maintaining liaisons with powerful proponents of acid rain controls in the U.S.

As the acid rain controversy continued between the Canadian and American governments, a distinct polarization of opinions began to emerge. The Canadian government began to receive vocal and influential support from U.S. senators who represented concerned citizens of the northeastern United States. These states were also recognizing serious impacts of increasing acidity in their own regions. The senators for these states began to lobby for changes in U.S. legislation that would reduce the amount of acidic deposition reaching their own borders. Due to these mutual concerns, several of these U.S. senators became very important allies in Canada's quest to influence a change in American air quality legislation. The shift in awareness by the American population combined with the backing of several powerful U.S. senators and a powerful Canadian lobby group are factors that can not be understated in resolving the acidic deposition issue. Without this shift in support, some analysts of this issue believe that Canada might still be requesting the United States to make changes to their emission control policies.

On the other end of the continuum, a very strong lobby group made up of Midwestern senators, utility industries and coal producers repeatedly impeded any plans to implement increased emission controls in the United States.

The powerful lobby groups that did not support pollution control measures were able to heavily influence government decision-making. These lobbyists argued on economic grounds, warning of massive unemployment and impeded economic growth. Many arguments were also put forward by those opposing any pollution controls measures. They included:

- There was no acid rain crisis.
- The existing legislation was already working and was strong enough.
- There was no direct evidence linking emissions from one region with acidic deposition in other regions.
- There was no accurate assessment of the impact and further studies would be necessary before spending large volumes of money on questionable controls.

Other arguments were directly targeted towards the Canadian position. These included:

- "Why should we be legislated to reduce emissions when they (Canadian Government) can't even control emissions in their own backyard?"
- "The Canadian utility companies would love to export their electricity. The sales would be much easier if we are forced to reduce or shut down our coal-fired generators so we become dependent on Canadian electricity. The whole issue is a Canadian conspiracy."
- "The Canadian people wanted free trade with us and encouraged economic growth. They are hardly the innocent party that they claim. Our largest customers for what we are producing are Canadians."
- "If we are forced to reduce pollutants, we will not be economically competitive with Canadians."

These arguments were not taken lightly by some American policy makers who already had mixed feelings about Canadian involvement. To some, the Canadians were viewed as meddlers in areas where they had no political right to belong. Others perceived the Canadian government as being weak and willing to bow to the requests and demands made upon them by the United States. These attitudes would not have given the Canadian government, standing alone, the power to influence any significant change in American policies. As American attitudes shifted and environmental lobbying intensified within its own borders, however, the road to improving air quality legislation in the U.S. began to take hold.

These events are now behind us. In 1990, the United States legislated amendments to their Clean Air Act that specifies commitment to reduce sulphur dioxide emissions. A year after the Clean Air Act was passed through Congress, the United States and Canada signed a Clean Air Accord that, among other things, provides a legal framework for resolving disputes pertaining to air quality. With the removal of these major stumbling blocks, the acidic deposition issue can now be dealt with in a more constructive manner. While much remains to be done, the initiatives to reduce the impact of acid rain have finally become a reality.

Economics of Acidic Deposition

What kind of response would you get if you asked a senior official of Canada's large smelting corporations about the economic impacts of acidic deposition? You might be told that the financial consequences of acidic deposition are primarily related to the cost of reducing emissions including the financial cost of research and development for more efficient technologies. The consequences might mean a loss of production due to the extra processing time, an increase in the cost of material fuel, the down time needed to retro fit existing equipment, the resulting lay-off of workers and the loss of market shares because competitors can undercut their prices. The economic consequences of acidic deposition for this company then, are primarily focused on the cost of reducing pollution and the resulting impact rather than on any environmental considerations.

In this section, you will have the opportunity to look at the acidic deposition issue strictly from an economic perspective. You will see how the costs of pollution controls are weighed against a variety of other factors that will greatly influence the decision-making process. The costs associated with implementing controls have been a significant contributor to the delays associated with resolving the acid rain issue. There are two distinct viewpoints associated with the economic side of this issue. By examining both of these perspectives, we will gain some insights that help explain why this issue has been so difficult to resolve. We will examine each of these perspectives separately. They are:

- Cost of implementing pollution controls
- Costs associated with not implementing pollution controls

The Cost of Implementing Pollution Controls

Removing sulphur dioxide and other emissions that contribute to the acidic deposition problem is an expensive business. Any industry that is involved in an emission reduction program is faced with expenses that do not help the productivity of that company. In other words, there is no profit to be gained from implementing any controls. This is the mind-set on which the normal operating procedures of industries were established right from the beginning of the Industrial Revolution. Without legislation in place to reduce emissions, few companies would implement aggressive pollution control measures on their own initiative. With pollution control legislation in place, industry is obligated to spend money on reducing emissions. Pollution control has been an accepted part of any industrial operation for many years. The debate lies not in whether there should be pollution controls, but rather, how much pollution control is considered to be acceptable. In this area, opinions vary dramatically. Some decision-makers want to leave the existing controls alone, others want to implement even greater controls.

Aside from the actual costs involved in changing the industrial process or adding new technology, there are other economic consequences of implementing pollution control measures. They include a depressed regional economy due to layoffs, increased costs passed on to consumers and a lack of industrial competitiveness with other similar industries not "weighed down" with pollution control costs. These factors have been used as arguments against implementing pollution control measures. Other arguments used by opponents of increased pollution controls include:

- The standards are too strict, unrealistic and unnecessary.
- Bureaucratic red tape makes it cheaper to build plants in other countries.
- The economic growth of their own country is prohibited.
- The cost of retrofitting is so expensive that the plant might just as well be shut down.
- Local unemployment figures will increase.
- It is impossible to find locations for new plants because the air or water is either too clean to be degraded or it is too deteriorated to allow more emissions.
- Pollution control adds to the rate of inflation and causes an increase in consumer prices.
- There is very little option in the way of alternatives.
- Environmental legislation is constantly being changed and this makes any long range planning very difficult.

When faced with these arguments, many decision-makers are expected to choose the options that would best meet the needs of the electorate. In some regions, implementing stronger pollution control measures would be considered a costly political mistake. Many of the more powerful lobbyists who use these arguments would no longer be supportive of a politician that is not sympathetic to their point of view.

The Costs Associated with NOT Implementing Pollution Control:

Calculating the costs of modifying the industrial process to reduce emissions or attaching a price tag for the installation of new pollution control equipment is relatively straightforward. On the other hand, trying to determine the cost of environmental damage is very difficult. Environmental resources such as lakes and ecosystems cannot easily be assigned a dollar value. Any losses associated with damage caused by acidic deposition would be hard to asses in terms of a specific amount. Some people would argue that there is no way that the environment can even be assessed with a dollar value and argue strongly against any attempts to do so. Nevertheless, some decision-makers have tried to determine the environmental costs associated with acidic deposition.

Without taking into account the costs associated with any environmental impacts, there are other consequences of acidic deposition that can be given a monetary value. Individuals who argue for increased pollution controls believe that these factors alone would be significant enough to warrant increasing pollution controls. Specifically, acidic deposition is believed to be responsible for the deterioration of man-made structures. These include monuments, buildings, metal structures (cars, bridges, etc.) and fabrics.

In addition, the decrease in tourism, the leaching of nutrients from soils resulting in agricultural failures, the loss of scenic areas and a decrease in human productivity due to health problems have all been linked to increased acidic deposition. The main argument from this perspective suggests that these factors are all long-term costs that will eventually outweigh the short-term savings gained by not spending money on pollution control. The principle argument can be summed up by using the familiar statement, "an ounce of prevention is worth a pound of cure".

Human Health and Acidic Deposition

An estimated 30,000 Canadians are drinking water that has increased levels of acidity. In addition, more Canadians are exposed to the airborne acidic particles that are associated with a variety of respiratory ailments including emphysema, asthma and lung cancer. Up to 50,000 deaths each year in the United States and Canada have been attributed to airborne sulphates.

There is also the possibility of becoming ill by drinking contaminated water. As water increases in acidity, it is able to leach out many types of toxic substances which can collect within the body. An increase in lead, mercury, aluminium and other heavy metals are associated with water that is higher in acidity. If water is acidic enough, the copper and lead found in plumbing can enter into the water supply. Lead, for example, is used as solder to join copper plumbing pipes together. If water is standing in the pipes for long periods of time (overnight for example), the concentration of these metals dissolved in the water increases. This could result in serious health problems for the individuals using that water. Young children are especially sensitive to lead and can suffer a variety of physical and neurological disorders. At present there are no known cases of lead poisoning caused by this phenomenon. Studies have confirmed, however, that there are elevated levels of lead in water that is more acidic. In some regions of Ontario and the northern United States, residents are drinking water supplies with increased acidity.

These health risks can be looked at from the economic perspective as well. The cost of providing medical attention to individuals with respiratory ailments attributed to acidic deposition is only one area of growing concern. There is also the loss of productivity due to employee absenteeism. The number of sick days that employees claim each year is a significant economic factor.

Generally speaking, although the short-term costs of implementing emission controls are tremendous, the long-term benefits associated with a healthier (cleaner) environment should not be underestimated. A cleaner environment has been estimated to cost taxpayers significantly less due to the lower cost of health care, improved economy and an increase in job productivity.

Sustainable Development

For many years, society has associated progress with increased economic growth. In turn, economic growth often continued without any significant regard for environmental consequences. Clean air and water as well as healthy ecosystems were often neglected during the quest for economic growth. This perception about progress was not born within the last twenty years, but has its roots firmly entrenched back to the Industrial Revolution. It seems that there has always been a discontinuity between economic and environmental concerns. During recent years, however, more individuals are giving this relationship a second look.

What is new in this relationship is the growing respect and concern that environmental considerations are being given. The time when economic considerations are given priority over environmental concerns is coming to an end. The price of progress is now being calculated differently. Economic growth will now be based upon economic and environmental policies that meet the needs of the present without compromising the ability of future generations to meet their own needs. This is the basic premise of Sustainable Development. The acid rain issue can be viewed as a testing ground for the implementation of this concept. In principle, the idea of sustainable development is attractive. Time will tell how acceptable the consequences of decisions and policies reflecting this new philosophy will be to Canadians.

There is no question that emissions from coal-fired electrical generators and mineral smelting plants in Canada and the United States are huge contributors to problems associated with acidic deposition. As consumers of these products and users of electricity we have become accomplices in the production of these harmful emissions. The years of acidic deposition have taken their toll on the ecosystems that have been exposed. We are at a point now where entire ecological regions are hanging in the balance. The road to recovery or continued deterioration will be based on the toughness of the decisions that are presently being made.

Is it possible to maintain a healthy economy and exercise environmental responsibility at the same time? Can we continue to use enough resources to meet our demands while reducing our environmental impact to meet the expectations of future generations? This is the goal of sustainable development. How do these goals apply to the acidic deposition situation that exists in North America today?

The first question that comes to mind is to find out what courses of action are considered to be sustainable. Other questions include what will be the long term benefits and, if this (sustainable development) is such a good idea, why is there opposition to these proposals and who is opposing them?

Decisions favouring sustainable development could include setting emission standards that stop environmental deterioration in even the most sensitive areas. Focusing specifically on emissions, however, is, as one politician put it "like putting a new exhaust system on an outdated car." What is really required is more initiatives at the pre-production end. This includes everything from changing the patterns of consumer demand, to developing new processing technologies. Achieving sustainable development will depend on communication and cooperation amongst individuals, industry and all levels of government. Each of these stakeholders has a role to play in attaining the goal of a sustainable economy.

The role of the individual

Individuals need to become more aware of these issues. Without this knowledge, the impetus to take positive action does not exist. Awareness is the first step. Positive actions that stem from this and are the responsibility of the individual include:

- being involved in the decision-making process
- sharing the cost of environmental decisions through the purchasing of environmentally responsible goods and services
- willing to pay for a cleaner environment
- taking advantage of recycling programs and local public transportation systems
- taking measures to reduce consumption of goods through practical conservation practises
- electing individuals who are environmentally conscientious

The role of industry:

Industry will be required to undertake initiatives that commit their energy and resources towards long-term environmental benefits. Their role will include the following practices:

- observing the laws and standards that exist
- continuing to research and develop more efficient methods of producing their product
- using raw materials that are the highest grade possible or, when unavailable, using appropriate pollution control technologies when using inferior raw materials
- willing to pay appropriately for the cost of suing air and water for emissions
- being sincere in their efforts to be environmentally responsible

The role of government:

Government responsibilities are to maintain a constant eye on the future and to develop policies and strategies that work towards this. It is imperative that government policies are not influenced by the short-term demands of various stakeholders. Specifically, the role of the government is to:

- institute legislation that reflects the concept of sustainable development
- ensure that the legislation being passed is strong enough to discourage law breakers
- make the initiative to communicate with other levels of government
- work towards international agreements to maintain economic competitiveness
- change foreign policies to reflect actions and initiatives being practised within their own borders
- demonstrate a sincere commitment to environmental initiatives

Summary

We live in an environment where over-consumption of our limited resources will have serious ecological and even economic impacts. At the most basic level, we have only two choices:

- to continue as we are and face the possible consequences of stressing our environment to the point where damage will be irreversible
- move towards a sustainable pace that eases the environmental impact, conserves our resources and merges sensible economic practises with a sound environmental ethic.

In resolving the acid rain issue, these goals can be realized. Through a cooperative and sincere effort by government, industry and the general public, a variety of options are available to realize the goal of sustainable development.

Suggested Socio-Economic Activities

Activity 11 - Video Investigation

The use of media to present issues can be very powerful. Media plays a role in influencing our perceptions and helps us to formulate our points of view as well as keeping us informed about local and global concerns.

This activity gives students the opportunity to design their own media presentation using the video camera. Students will be involved in research, issue evaluation, development of communication skills, and influencing others into taking positive action.

Students should be encouraged to evaluate various perspectives, to investigate as many angles of the issue as they can, to provide some background information to their audience, and to formulate various solutions that might resolve this issue.

Students might also be encouraged to make predictions of future scenarios based on information that they have collected during their investigations.

The style in which you choose to develop your video presentation can include the following choices:

- expository
- humour/satire
- bleak/pessimistic
- optimistic
- documentary
- story
- news story
- investigative
- sensational

The following are suggestions that you might wish to include when you are developing your video presentation:

- research
- communication of background information
- setting up the scenario (i.e. what is acidic deposition, what are its effects, who is worried about it, what are the local, regional, global concerns?)
- what is the cause of acidic deposition (industrial, individual contributions, eastern/western situation?)
- how does the Alberta situation differ and/or compare to the situation in eastern North America?
- set up real or mock interviews to present the background scenario with experts, concerned interest groups and industry (interviews from various points of view should be represented). Note: If you choose to use "actors" as your experts, be careful not to stereotype the characters (unless the style you have chosen is a satire where you are trying to get your message across using humour or irony).

The socio-economic angle; possibly consider using the story of a family forced to move as a result of decision or circumstances (i.e. crops failing, perceived poor health, job lay-off due to plant shut down)

Steps to consider when designing your video presentation:

- scripting
- shooting
- editing
- playback
- questions/evaluations

This project should consist of two parts:

- Research and written component to be handed in
- Communication (video production) – the actual quality of the video production is not expected to be similar to a professionally edited work of video journalism. It should, however, demonstrate that good research, critical thinking and analysis of issues have occurred.

Activity 12 – Conducting a Poll

The latest polls addressing the top ten concerns among Canadians provides a good reflection of the current attitudes and concerns that we believe warrant the most attention. Economic and environmental issues are never left out of this top ten list. Polls are not only important as a means of determining the mind-set of a population but they also help to persuade individuals who have not yet made up their minds. Politicians recognize the value of polls and often make their decisions accordingly.

In Alberta, when we consider all of the environmental concerns, acidic deposition is not ranked very high. Many individuals would say that Alberta simply does not have an acidic deposition problem. There are other voices who would loudly object to this conclusion and are very concerned about the potential for environmental damage in certain areas of Alberta as a result of acidic deposition.

Your project is to conduct a survey in order to come up with a comprehensive report that indicates how much Albertans really know about acidic deposition. This can include finding out:

- the base of knowledge that might be common to the majority of individuals
- the ability of individuals to distinguish acidic deposition concerns in Alberta from eastern Canada
- their ideas about who is responsible
- the amount of concern this issue has in relation to other issues
- the ideas about potential solutions
- their hope for a resolution (i.e. what are their feelings about the issue being resolved, are they optimistic or pessimistic, and who should absorb the costs of any pollution control strategies?)

A survey question should not deliberately lead the person responding to your poll towards a specific response. Any personal biases you might have should not be reflected in the way you ask the questions. Remember you are investigating what that person thinks, therefore you must be neutral in your questioning approach. The questions should be thoughtfully constructed so as to reflect the opinion of the individual being polled. Examples of polls made by professional organizations can help you design your questions.

Points to consider in designing your survey:

- Short answers to questions will make summarizing the information easier and will help you when you are drawing your conclusions.
- Make certain that the question is very clear and is asking exactly the type of information you are seeking.
- Some questions can be used to judge basic knowledge of the individual who is responding. This can be used to evaluate any later responses (i.e. highly informed vs. poorly informed).

- Choose the survey sample at random. You may, however, want to categorize the survey sample into distinct groups (i.e. high school groups, general public and industry representatives) to see if any similarities or differences exist.

Design your questions to obtain the following information:

- the extent to which people know what acidic deposition is
- the extent to which people are concerned about acidic deposition
- extent to which people are aware of the sources and causes of acidic deposition
- ranking of acidic deposition with other concerns
- the amount of personal responsibility the individual feels for the situation
- the degree to which they feel powerful or helpless in resolving the situation

Activity 13 - Essay Writing

Choose one of the following arguments and write an essay to support or disagree with the position stated in the argument.

Argument #1

Examining the costs of implementing pollution control and comparing these to the costs of doing without these controls is one way of trying to reach a decision about whether or not pollution controls should be implemented. There are however, other factors to be considered in looking at the economics of acidic deposition.

Historically people have regarded air and water as a right to which all people are entitled. Extending this argument would mean that industry also has a right to this air and water. Until recently, companies did not consider the costs of using air and water. This has led to wide scale misuse and abuse of our limited natural resources to which we are all entitled. If companies have to pay the costs associated with bringing in raw materials (labour and transportation) as well as the cost of the manufacturing process, then they should also be responsible for paying for the air and water that they use.

By charging a fee to those who use this resource, the air or water being used becomes a part of the regular pricing system and has its own economic value. This would act as an incentive for industries to use the resource with more discretion and care. Because clean air and water are resources that are limited, any activity that can degrade them should be held accountable through economic pricing incentives and stronger legislation. These two factors will serve as effective tools that will protect our environment for future generations. If the fee charged for using these resources is high enough, this will provide a great incentive for industries to use the resource as efficiently as possible. There will also be more effort spent on finding alternative procedures that will reduce their costs even further.

Argument #2

The sour gas refining industry in Alberta is responsible for releasing sulphur dioxide into the atmosphere. Some of the smaller refineries were, at one time, permitted to flare off the hydrogen sulphide contained within the gas. Larger refineries were responsible for capturing over 98% of

the sulphur dioxide created by the refining process. Selling the sulphur that is recovered as the end product of this pollution control technique can offset most of the money used to initially capture this pollution. In order to remove the remaining 2% of the sulphur dioxide, the pollution control costs would increase dramatically to more than the initial cost of removing the first 98%.

Although 2% does not seem like a significant amount, the actual volumes are very large because of the large volumes of natural gas being refined daily. For this reason, all refineries should be subject to 100% sulphur dioxide reduction legislation.

Activity 14 - Design a Chronological Map of the Acidic Deposition Issue

The history and evolution of the acidic deposition issue is interesting and complex. One way of becoming more familiar with the different events surrounding this issue is to reconstruct the history by making a chronological display. Each group will be responsible for choosing what perspective of the acid deposition problem they would like to follow. Examples include the economic side, the political angle or the science and technology perspective. Once the direction has been selected the groups will be responsible for researching the information. Copies of newspaper headlines can be used to make the display more effective.

An alternative to having each group make a chronological map is to have the entire class in one large project with different groups being responsible for different years or events. This large chronological map could then be displayed along the length of the classroom wall.

Activity 15 - Acidic Deposition in the Headlines

Search through past newspapers or magazines and find several articles that address the same aspect of the acidic deposition issue. After reading through the articles:

- Determine who the major stakeholders are and list their main concerns.
- Choose one of the stakeholders that you have identified.
- Describe the main arguments that have been presented to oppose this view.
- Determine the rebuttal arguments that this stakeholder would use to defend the opposing arguments.
- Are there any potential avenues for conflict resolution? List and describe them.

Activity 16 - Fact or Fiction

Choose one of the following statements and after deciding whether you agree or disagree with the statement, prepare a report that uses researched material supporting the viewpoint you have selected.

- Acid rain has become a significant issue for Canadian citizens.
- The acid rain issue has taken over 15 years to be resolved.
- The Canadian government has applied extensive lobbying measures aimed at the United States to reduce American SO_2 emissions.
- Acid rain has long-term economic consequences.
- There are control measures that can significantly reduce acidic emissions but, for various reasons, they are not always used.
- Canadian and American positions on acid rain are very different because of regional differences.
- Economics are behind the decisions regarding acid rain control policies.
- A bilateral air quality accord with the U.S. does not guarantee a successful solution to the acid rain problem in Canada.
- The Canadian federal government is restricted in determining pollution standards because most of the pollution control legislation lies within the provincial governments.